Fraser River Estuary
Management Program

WATER QUALITY PLAN
Monitoring and Objectives

**Standing Committee on the Fraser River
Estuary Water Quality Plan**

April, 1991

Government of Canada
Gouvernement du Canada

BC
Province of
British Columbia

BC
F703.F7
[illegible]
1990
c. 3

FRASER RIVER ESTUARY MANAGEMENT PROGRAM

WATER QUALITY PLAN - 1990
Monitoring and Objectives

Standing Committee on the Fraser River
Estuary Water Quality Plan

April 1991

PREFACE

This Draft Water Quality Plan has not been reviewed or approved by the management of the agencies named in the document. Certain parts of the Plan may be significantly changed once agency review has been completed. Costs attributed to the monitoring program are estimates only and future funding arrangements will be addressed by the FREMP Management Committee Executive and involved agencies in the next phase.

EXECUTIVE SUMMARY

The Fraser River Estuary supports a wide variety of wildlife and fish species, including economically important Pacific salmon and waterfowl. As well, the Fraser River Estuary supports diverse recreational, urban and industrial uses. In general, the quality of the environment is good, but in some instances it has been adversely affected by urban and industrial development. Wildlife and fish, and in some cases recreation, may be threatened because of toxic effluents, the release of persistent contaminants or by habitat destruction. Action is needed to determine accurately the quality of the environment and identify means of bringing about necessary improvements.

The purpose of the Fraser River Estuary Water Quality Plan is to establish: 1) agreed upon water quality objectives throughout the study area and 2) a coordinated environmental monitoring program, the results of which can be used to assess the health of the estuary, determine the adequacy of the water quality objectives and the adequacy of waste treatment and disposal to protect aquatic resources. These activities address the overall goal of the Fraser River Estuary Management Program which is to maintain, and where possible, improve the environmental quality of the estuary.

This report reviews existing programs designed to define and improve environmental quality. These programs include the Fraser River Estuary Management Program, North Fraser Harbour Environmental Management Plan, Fraser River Harbour Environmental Management Plan and the Greater Vancouver Regional District Liquid Waste Management Plan.

Sources of contaminants entering the Fraser River Estuary are discussed under the following categories: municipal and industrial liquid waste discharges, including stormwater and combined sewer overflows, non-point source discharges (e.g. leachates and agricultural runoff), dredging and dumping of sediments, upstream sources and atmospheric inputs. The development of a Water Quality Plan requires a comprehensive review of the foregoing sources because the contaminants discharged can cause toxic impacts and degrade habitat for fish and wildlife populations.

Water Quality Objectives are limits set for physical, chemical or biological characteristics of water, sediment or biota which will protect designated water uses and are one instrument used in protecting and improving the quality of the estuary. A mechanism is provided in this plan for the establishment of agreed upon Water Quality Objectives. The information used to establish a new or revised Water Quality Objective is similar to that used by the provincial government in setting provisional objectives. A monitoring program to assess compliance with the Objectives is discussed as are a number of priority areas for Objectives development.

A major component of the Water Quality Plan is a coordinated monitoring program designed to: 1) determine the current status of ambient environmental quality, assess trends and gauge compliance with Water Quality Objectives; 2) obtain data in sloughs where environmental extremes may occur; 3) identify areas where enforcement and/or abatement action may be needed; and 4) provide information for the revision and development of Water Quality Objectives. The monitoring program operates on a three-year cycle with effluent and water sampling conducted during the first year; sampling of sediments, invertebrates, heron eggs and water in the second year; and fish and water in the third year. Effluent sampling in Year One would be directed at establishing priorities for sampling of sediments, invertebrates and fish in the subsequent hydrological cycle. Sediments and invertebrates would be sampled toward the end of fiscal Year Two; with fish sampling occurring early in fiscal Year Three, within the same prefreshet hydrological cycle. This apportionment of work addresses both technical and financial considerations in the planning and implementation of the program. The number of sampling sites and species of biota, chemical analyses, replicates and quality assurance/quality control procedures were selected to provide the minimum level of information required to adequately assess the quality of the environment. The three-year cycle will produce trend data for contaminants in the estuary and allow assessment of the degree of contamination of receiving waters and biota. Resources beyond those identified for the monitoring program would be required to improve understanding of the acute and chronic effects of contaminants on biota.

The monitoring program will interface closely with other FREMP programs, especially implementation of the Waste Management Plan, and with other monitoring and research activities outside FREMP to ensure effectiveness and cost efficiency. A number of federal, provincial and municipal agencies currently conduct monitoring programs in the study area. These, along with other monitoring programs, will be coordinated through the Water Quality Standing Committee in order to avoid duplication and to focus effort into appropriate areas.

A number of Special Studies which concentrate on specific environmental problems in the estuary or have a definite research orientation are identified in the Plan. Such programs if implemented, would provide an information base for refining the routine monitoring program.

Coordination of the Water Quality Plan is the responsibility of the Standing Committee, including: budgeting, approval of revisions to the Plan, identification of research needs, establishment of contract requirements and Water Quality Objectives and review and approval of reports submitted by contractors carrying out the monitoring program. Day to day administrative aspects of the Water Quality Plan will be managed by a Plan

Coordinator reporting to the Standing Committee. The Plan Coordinator's responsibilities will include managing monitoring program implementation, supervising contractors, coordinating data management, preparation of draft reports and organizing public information activities. The Plan Coordinator will be supported by a Quality Assurance/Quality Control Officer responsible for all aspects of sampling, analysis and data handling. The Plan Coordinator and the QA/QC officer could either be contract employees or new government employees added to the complements of participating agencies. The current cost estimate for the Water Quality Plan is approximately $3.7 million (funding has not yet been approved), for a three-year cycle.

STANDING COMMITTEE

FRASER RIVER ESTUARY WATER QUALITY PLAN

S.C. Samis (Chairman)	Habitat Management Division Department of Fisheries and Oceans
L.M. Churchland	Inland Waters Environment Canada
M.J.R. Clark	Environmental Protection Division B.C. Environment
R. Jones	Greater Vancouver Regional District
W.M. Pomeroy	Environmental Protection Environment Canada
L.G. Swain	Water Quality Branch B.C. Environment
D.G. Walton	Environmental Protection Division Lower Mainland Region B.C. Environment

TABLE OF CONTENTS

PREFACE i

EXECUTIVE SUMMARY ii

STANDING COMMITTEE vi

LIST OF TABLES ix

LIST OF FIGURES x

LIST OF APPENDICES xi

ACKNOWLEDGEMENTS xii

1.0 INTRODUCTION 1

Hydrology 1

Predicted Demographic Changes 2

Uses of the Fraser River Estuary 3
- 1.1 Current Environmental Quality 5
- 1.2 Programs to Define and Improve Environmental Quality 8
  - 1.2.1 The Fraser River Estuary Study (FRES) 8
  - 1.2.2 The Standing Committee on the Fraser River Estuary Water Quality Plan 9
  - 1.2.3 North Fraser Harbour Environmental Management Plan 11
  - 1.2.4 Fraser River Harbour Environmental Management Plan 11
  - 1.2.5 Greater Vancouver Regional District Liquid Waste Management Plan 12
- 1.3 Legislation and Agency Jurisdictions 12

2.0 WATER QUALITY PLAN 13
- 2.1 Introduction 13
  - 2.1.1 Overview 13
  - 2.1.2 Sources of Pollutants in the Fraser River Estuary 14
  - 2.1.3 Principal Water Uses and User Groups 19
- 2.2 Water Quality Objectives for the Fraser River Estuary 20
  - 2.2.1 Mechanism for Development of Agreed-upon Water Quality Objectives 21
  - 2.2.2 Documentation for Development of Objectives . 22
  - 2.2.3 Objectives Monitoring 25

2.2.4 Priority Issues for Objectives Development . 26
2.2.5 Attainment of Objectives 27
2.2.6 Interim Criteria and Guidelines 29
2.3 Recommended Monitoring Program 30
2.3.1 Introduction 30
2.3.2 Program Goals 31
2.3.3 Ambient Monitoring Program Development Guidelines 31
2.3.4 Guidelines for Special Studies and Research . 34
2.3.5 Existing Monitoring Programs 35
2.3.6 Recommended Ambient Monitoring Program . . . 35
2.3.6.1 Protocols for Sampling and Quality Control/Quality Assurance 37
2.3.6.2 Effluent 38
2.3.6.3 Water 40
2.3.6.4 Sediments 42
2.3.6.5 Biota 43
2.3.7 Data Management, Interpretation and Reporting 46
2.3.8 Program Priorization 47
2.3.9 Funding and Personnel Requirements 48
2.3.10 Monitoring Program Coordination and Implementation 49
2.3.10.1 Coordination 49
2.3.10.2 Implementation 50
2.4 Required and Suggested Special Studies 51
2.5 Pollution Related Enforcement Procedures 52
2.6 Public Education and Involvement 52
2.7 Interactions With Other FREMP Activities 55

3.0 PLAN IMPLEMENTATION 56

TABLES 59-72

FIGURES 73-82

REFERENCES 83-90

APPENDICES 91-133

LIST OF TABLES

Table Page

1 An overview of legislation applicable to water quality management in the Fraser River Estuary 59

2 Summary of waste discharges by type in each of the three Fraser River Reaches and adjacent land areas 60

3 Summary of principal estuary uses and user groups 61

4 Summary of recommended monitoring program activities for the three-year cycle 62

5 Summary of field monitoring sites, compartments and replicates for the recommended monitoring program 63

6 Recommended effluent discharge monitoring 64

7 Recommended FREMP upstream reference site water quality monitoring program 65

8 List of biota proposed for monitoring 66

9 Summary of field personnel requirements (days) 67

10 Monitoring program - analytical cost estimates 68

11 Monitoring program - total cost estimates 69

12 Suggested Special Studies 70

13 Proposed duties - Standing Committee and Plan Coordinator 71

14 Water Quality Plan costs - estimated for three-year plan cycle 72

LIST OF FIGURES

Figure Page

1 The Fraser River Estuary Management Program study area 73

2 Reporting structure and relationship of FREMP committees and work groups 74

3 Roles of the Water Quality Plan Standing Committee 75

4 Key components in updating the Water Quality Plan 76

5 Discharges into the lower Fraser River under provincial permit 77

6 Combined sewer overflows into the lower Fraser River 78

7 Sites of antisapstain chemical usage in the lower Fraser River 79

8 Point source stormwater discharges into the lower Fraser River 80

9 Mechanism to develop agreed-upon Water Quality Objectives for the FREMP study area 81

10 FREMP Water Quality Plan monitoring sites 82

LIST OF APPENDICES

I Legislation and agency jurisdictions 92

II Ministry of Environment Provisional Water Quality Objectives for the Fraser River Estuary 104

III Monitoring roles in the region 116

IV Quality Assurance/Quality Control 124

V List of Water Quality Criteria 130

ACKNOWLEDGEMENTS

The Standing Committee on the Fraser River Estuary Water Quality Plan acknowledges the assistance of several individuals and groups who have contributed to the preparation of this Plan. The FREMP Management Committee Executive has provided guidance to the Committee. Consultation with public interest groups in January 1987 and with representatives of Lower Mainland municipalities in November 1987 provided insight into their perceptions of the estuary and FREMP. A first draft of this plan was reviewed by the public in December 1990; followed by a subsequent review and public meeting in June 1991.

1.0 INTRODUCTION

Hydrology

The Fraser River starts in the Rocky Mountains at Mount Robson Park, drains an area of approximately 230,000 square kilometres, and flows 1400 kilometres to its outlet in the Strait of Georgia near Vancouver, British Columbia. At New Westminster, the Fraser River Main Stem divides to form two major channels, the North Arm and Main Arm, which carry approximately 15 and 85 percent of the river flow, respectively.

Two flow regimes are exhibited by the Fraser River system. Reflecting snow melt, the Fraser and most of its tributaries have peak flows in late spring (Water Survey of Canada 1985). Flows remain high through the summer due to continuing snow melt and are reduced to low flow in late winter. During high flow in May to July, a heavy concentration of suspended sediment is transported downstream, contributing to accretion in river channels and on the delta-front (McLean and Church 1986).

Water movement in the lower Fraser River is a function of both tides from the Strait of Georgia and of the river discharge (Kennett and McPhee 1988). Below Hope, the rapid descent of the Fraser River decreases and tidal effects become evident. The tide in the Strait of Georgia affects water levels in the river as far upstream as Chilliwack (90 km upstream) at low flow, and only as far as Mission (60 km upstream) during high flow periods. The tide also affects water levels of the Pitt River (25 km upstream) and Pitt Lake.

The direction and characteristics of river flow in the lower portion of the river depend in part on the stage of the tide (Ages and Woollard 1976). During flood tide at low flow, the outward river flow reverses and water accumulates in the delta and upstream river channels. At ebb tide, this "stored" water is released, increasing the outflow. Typically, the ebb tide is of longer duration than the flood tide. River "training" structures restrict the channel width and maintain velocities sufficiently great to scour sediment from the bottom, reducing the need for dredging to maintain channel depth for shipping (Kennett and McPhee 1988).

Flow reversals in the river complicate the environmental impact evaluation of point source discharges (Kennett and McPhee 1988). River velocities vary widely in magnitude and direction as a result of changes in flow and tidal conditions. Changing river velocity results in varying dilutions of effluents and residence times of contaminants in the river (Swain and Holms 1985). Computer modelling and dye tracer studies indicate that water may pass a discharge point several times, leading to multiple dosing (Swain and Holms 1985).

An important feature affecting the flow distribution in the estuary is the intrusion of dense saline water from the Strait of Georgia (Ages 1979). This dense water is forced upstream in the form of a subsurface "salt wedge" by a rising tide and is subsequently moved downstream on a falling tide. The salt wedge reduces the cross-sectional area available for river outflow, thus accelerating surface currents. At very high tides mixed saline water may penetrate as far upstream as New Westminster in the Main Arm (20 km upstream) (Kennett and McPhee 1988).

Predicted Demographic Changes

The Greater Vancouver Regional District (GVRD) projected population and land use patterns to the years 2006 and 2036 during preparation of a Liquid Waste Management Plan (GVRD 1989). The population of Greater Vancouver is expected to increase from

1,380,000 in 1986 to 1,710,000 in 2006 and to 1,900,000 in 2036. This represents a reduced annual growth rate from the current level to 0.9% by 2006 and to 0.1% by 2036. However, an overall population increase of 25% is projected to occur between 1986 and 2006, and a 40% increase is forecast from 1986 to 2036.

The estimated volume of effluent from municipal treatment plants discharged into the estuary based on population projections will increase by 25% from the present to 2006, and by 40% to 2036. There may be concurrent increases in industrial wastewater discharges either directly into the river or indirectly through the municipal sewage treatment plants. These increased discharge volumes could have significant impacts on ambient water quality characteristics in the Fraser River if existing treatment and disposal practices are not improved.

The forecasted increase in population in the FREMP study area in future years will change land use patterns; for example, some agriculture will be displaced by urban use. Point source stormwater discharges into the estuary will increase due to paving of land. Additionally, the quality of the stormwater is expected to change in response to increased urbanization.

Uses of the Fraser River Estuary

The Fraser River Estuary supports many activities which may compete for use of the aquatic environment (Standing Committee 1988). Fraser River salmon runs are the largest in the world, with major commercial catches of all five Pacific species, important native food fisheries and significant sports fisheries (DFO 1989a). There are also important non-salmonid fisheries. The Fraser River delta is a major resting and feeding area for migratory birds on the Pacific flyway (Butler 1986; Savard 1985). The estuary and delta support the many forms of aquatic life at lower trophic levels which fish, birds, and other wildlife utilize as food. The estuary is also used extensively for recreation including boating, hunting, bird-watching, hiking and swimming (Fraser Estuary Study Recreation Work Group 1978).

The estuary has a zone of intense urban and industrial activity which can exert a negative impact on the aquatic ecosystem (Slaymaker and Lavkulich 1978; Fraser River Estuary Study Committee 1978). Industrial effluents (Swain 1980) and landfill leachates (Swain and Rocchini 1983), typically following treatment, are discharged directly into the river, or may be collected and discharged via sewage treatment plants. The lower Fraser River receives large volumes of municipal sewage (Cain and Swain 1980) which have undergone primary treatment including seasonal chlorination and dechlorination at two major sewage treatment plants. The 1988 outfall extension from the Iona primary treatment plant relocated the discharge from the Sturgeon Bank intertidal zone to the Strait of Georgia (out of the study area). The effluent is now discharged at depth into Georgia Strait and is not chlorinated. In addition, the estuary receives stormwater (Swain 1983) and combined sewer overflows (periodic discharges of mixed, untreated sewage and stormwater) from numerous point and non-point source discharges. The river is dredged frequently and is a major shipping corridor (Kennett and McPhee 1988). Log booms are transported and stored along the shores (FREMP Log Management Activity Program 1987). Several sawmills employing treatment for control of sapstain fungus on freshly cut lumber discharge stormwater under a provincial Regulation that stipulates maximum levels of fungicide compounds to protect receiving waters (B.C. *Waste Management Act* 1982). In addition, one paper mill directly discharges process effluents into the lower Fraser River (Standing Committee 1987a). The water of the Fraser River is used by industry in a minor way for process and cooling water (Supervisory/Coordinating Committee 1987). Intensive agricultural activities on the Fraser delta require water for irrigation and produce runoff that contains measurable quantities of pesticides (Wan 1989) which enters Main Stem and slough areas.

The Fraser River is not used as a source of domestic water by the communities within the FREMP study area. Drinking water is taken from streams on the western slopes of the Coast Range. Such streams are naturally somewhat acidic as is the rainfall and can be chemically "aggressive". Consequently, in addition to industrial sources, heavy metals including lead, copper and zinc occur in our coastal area in sewage and stormwater from plumbing fixtures and galvanized structures.

1.1 Current Environmental Quality

Quality of water, sediment and biota in the lower Fraser River was assessed in 1987 and 1990 through a review of existing monitoring and research data (Standing Committee 1987a; 1990).

Contaminant levels are not easily measured or interpreted in the Fraser River Estuary (Hall 1985) due to dilution, tidal action, bioconcentration and seasonal change. However, available data (Standing Committee 1987a; 1990) for water, sediments and biota indicate that areas of specific degradation exist. The worst degradation occurs in the North Arm, where river flow is relatively low and a large number of stormwater and combined sewage overflows together with mostly minor industrial effluent discharges occur. Conditions in the Main Stem are generally not significantly degraded. Those reaches of the Main Arm where primary sewage discharges occur are intermediate in terms of degradation between the North Arm and Main Stem. Some toxic contaminants are of concern in the estuary and may require further study/remedial actions to control inputs into the river. Examples of contaminants requiring such attention include antisapstain chemicals, polycyclic aromatic hydrocarbons and dioxins/furans. These contaminants are similarly a concern for the upper Fraser River basin.

Prior to relocation of the Iona Island primary sewage treatment plant (STP) outfall to a deep marine location in 1988 there existed a zone of severe degradation over a limited area of Sturgeon Bank near the previous discharge point (Standing Committee 1987a). The extension of this outfall has improved water quality on Sturgeon Bank and the degraded area has begun to recover.

Low dissolved oxygen, habitat loss or alteration, and contamination by metals and organic compounds were documented problems resulting from the historic sewage discharge onto Sturgeon Bank (Stancil 1980). Metals may exhibit greater bioavailability at the salt wedge-freshwater interface and it is believed that this is the case on Sturgeon Bank (Kennett and McPhee 1988).

A 1980 survey of Fraser River fish from the headwaters to the mouth (Singleton 1983) indicated that many metals levels in fish muscle remained the same or declined when compared with results of a 1972 survey (Northcote et al. 1975). Further reductions from 1980 levels were evident for fish collected from the estuary in 1988 (Swain and Walton 1989). Elevated metals levels in 1980 in fish tissue were attributed to man's activities, except perhaps for copper, which was higher upstream from developed areas. The cause for the high copper is unknown. Concentrations of metals in migrating adult sockeye salmon sampled in 1987 and 1988 in the Fraser River from Steveston to Prince George were at or near detection limits and posed no risk to consumers (DFO unpublished data 1987; 1989b).

Apparent bioconcentration of metals from sediments by benthic organisms was noted for copper, lead and zinc in the Main Stem, Main Arm and North Arm (Singleton 1983). Some differences were noted between data for metals in sediments and benthic organisms from 1985 and those reported earlier (Swain 1986). These differences could be real or may be artifacts of sampling location or time of year. In the Main Stem, copper and iron in some benthic organisms appeared to increase moderately, while in the Main Arm, copper and lead in sediments appeared to double between 1980 and 1985 (Swain 1986). However, an adequate database is not yet available on which to judge whether Fraser River Estuary conditions are deteriorating or improving in terms of these parameters.

The sloughs and side channels are the most sensitive areas for fish and aquatic life in the estuary (Birtwell et al. 1987; Levy and Northcote 1982). There is concern that fish may be impacted by low dissolved oxygen, organic contaminants and metals in such areas, and therefore more information will be collected in the monitoring program.

Bacteriological contamination in Boundary Bay has prevented commercial bivalve harvesting for the last two decades (Ferguson and Kay 1978; Standing Committee 1989). In tributaries to Boundary Bay, dissolved oxygen levels can decrease seasonally to lethal levels because of decomposing organic material from agricultural runoff, conditions which are potentially exacerbated by pesticide residues (Kennett and McPhee 1988). Bacteriological quality on the south side of the North Arm jetty (i.e. Iona Beach) has improved significantly following relocation of the STP outfall into Georgia Strait (GVS & DD 1990).

The water chemistry of Sturgeon and Roberts Banks is similar although there was a high level of variability between sampling occasions and in comparison to previous studies (Standing Committee 1987a). Seven organic compounds and eight inorganic compounds were detected in sediments in 1986; however, concentrations of all organics, except phthalate esters, were within twice the detection limit and were below concentrations of concern where such standards exist. The eight inorganic compounds detected were at similar levels on Roberts and Sturgeon Banks and at relatively uniform concentrations over time (Standing Committee 1987a). Runoff from agricultural lands is believed to be a major source of inorganic contamination (e.g. ammonia) potentially leading to localized toxic conditions in tributaries to Boundary Bay.

1.2 Programs to Define and Improve Environmental Quality

Conflicting/competing water uses in the estuary, information gaps relating to environmental quality, and the need to maintain or improve environmental quality prompted the initial establishment of the federal/provincial program for the Fraser River Estuary.

1.2.1 The Fraser River Estuary Study (FRES)

In 1977-78, the Canada/British Columbia FRES was established to develop a management plan for the estuary. As part of Phase I of FRES, a Water Quality Work Group was established which published 16 technical and ancillary reports on water quality and a summary report (Water Quality Work Group 1979). In summary these reports found no major estuary-wide environmental degradation, but did identify a number of reach-specific problems plus numerous important data gaps.

Phase II of FRES (1979-82) focused on the development of a proposed management program (Fraser River Estuary Study 1982) for the Fraser River Estuary. During Phase II, a federal/provincial committee was formed, which designed a monitoring program titled: Fraser River Estuary Monitoring, A Recommended Approach (Working Committee on Fraser River Estuary Monitoring 1984). Concurrent with this process, the B.C. Ministry of Environment developed provisional water quality objectives in reports titled: Fraser-Delta Area, Fraser River Sub-basin from Kanaka Creek to the Mouth, Water Quality Assessment and Objectives (Swain and Holms 1985) and Boundary Bay and its Tributaries, Water Quality Assessment and Objectives (Swain and Holms 1988).

1.2.2 The Standing Committee on the Fraser River Estuary Water Quality Plan

The Fraser River Estuary Management Program (FREMP) builds upon past achievements under FRES through adoption of common objectives and coordination of activities among agencies. One of the major goals of FREMP is to "maintain ambient water quality levels in the Fraser River, outer estuary and Boundary and Semiahmoo Bays that will ensure the preservation of fisheries and wildlife and, where suitable, provide for water contact recreation". The estuary is shown in Figure 1.

A major objective of FREMP is to improve management decision making in an estuary-wide context by providing all agencies involved in managing the estuary with adequate opportunity to participate. Although it would be ideal to identify a single management plan, the existing complexity of jurisdictions and relationships among agencies has resulted in the linking of several plans and activity programs, each under the jurisdiction of an appropriate lead agency and all overseen by the FREMP Management Committee (Figure 2). This "linked management" approach was determined to be preferable to the establishment of a single agency to deal with issues in the estuary.

Eight major activities in the estuary have been identified which involve more than one level of government and hence require coordinated management. FREMP Activity Program Work Groups (e.g. Waste Management Activity Program) comprised of agency representatives and user groups (e.g. industry) are examining these activities and developing guidelines on their management. The Waste Management Activity Program has developed a Plan to facilitate integrated discharge management.

In order to improve current approaches to water quality management in the estuary and to promote the coordinated review of development projects, the FREMP Management Committee established two long-term committees: the Standing Committee on the Fraser River Estuary Water Quality Plan and the Environmental Review Committee.

The Standing Committee consists of three provincial and three federal representatives and one member from the Greater Vancouver Regional District. The purpose of the committee is to develop a Water Quality Plan for the estuary to ensure its long-term protection. The plan is the subject of this report. The plan will include provisions for ambient water quality objectives for the study area, and recommendations for a coordinated monitoring program. The overall goal of the plan is to contribute to the maintenance and, where possible, improvement of the environmental quality of the estuary.

The duties of the FREMP Committee on the Water Quality Plan also include advising the Management Committee Executive on water quality matters, providing at regular intervals a Status Report on Water Quality and advising the Executive regarding procedures for public input and public information exchange. The roles of the Standing Committee are shown in Figure 2.

The Water Quality Standing Committee has completed several tasks to date. In January 1987, the Committee met with public interest groups to solicit input into a Water Quality Plan and to discuss mechanisms for ongoing public involvement. Since 1987, annual workshops were held where those studying the estuary discussed their recent findings and reviewed current projects. The results of the February 1987 workshop formed the basis of the first Fraser River Estuary Status Report on Water Quality (Standing Committee on the Fraser River Estuary Water Quality Plan 1987a), a document which provides an overview of the health of the estuary.

The results of the subsequent workshops have been incorporated into the 1990 Status Report (Standing Committee on the Fraser River Estuary Water Quality Plan 1990). In September 1987, the first Report summarizing current research and monitoring activities in the estuary was published (Standing Committee on the Fraser River Estuary Water Quality Plan 1987b).

The Water Quality Plan contained in the present report will be revised and updated in future years as required.

1.2.3 North Fraser Harbour Environmental Management Plan

In September 1988, the North Fraser Harbour Commission (NFHC) and the Department of Fisheries and Oceans (DFO) released a management plan (DFO and NFHC 1989) which allows for controlled development along the North Arm of the Fraser River while safeguarding habitat vital to salmon and other aquatic life.

1.2.4 Fraser River Harbour Environmental Management Plan

The Department of Fisheries and Oceans and the Fraser River Harbour Commission released a plan for the Main Stem and Main Arm in July 1990 to complement the North Fraser Plan (DFO and FRHC 1990). This plan used a shoreline habitat classification scheme and inventory to provide a basis upon which the acceptability of industrial or commercial development can be judged and any mitigation and compensation determined. The plan sets out project review and assessment procedures, allows for a habitat compensation bank and establishes cooperative management programs.

1.2.5 Greater Vancouver Regional District Liquid Waste Management Plan

A Liquid Waste Management Plan (LWMP) is a blueprint for the management and disposal of sewage and stormwater within a given geographical area. The B.C. *Waste Management Act* (1982) established the waste management plan concept. Under the Act, approval of a waste management plan by the Provincial Minister of Environment authorizes a municipality or Regional District to discharge waste in accordance with an approved plan.

The GVRD Plan, Phase I of which was completed in 1989 (GVRD 1989), has broad implications for the Fraser River Estuary in terms of possible reduced waste loads from sewage treatment plant discharges, combined sewer overflows and stormwater discharges. In addition, environmental monitoring that may be carried out under the LWMP would provide information on water quality to FREMP, probably on an ongoing basis. The Minister of Environment (Provincial) has directed the GVRD to go to secondary treatment of Annacis and Lulu Island sewage treatment plants.

1.3 Legislation and Agency Jurisdictions

Appendix I contains an outline of key environmental legislation in Canada and British Columbia, with relevance to FREMP. A guide to the use of environmental legislation is contained in Table 1. The principal Acts for the management of water quality in the Fraser River Estuary are the federal *Fisheries Act* and *Canadian Environmental Protection Act*, and the provincial *Environment Management Act* (B.C.) and *Waste Management Act* (B.C.). The other Acts outlined in Table 1 are used less frequently, although topics dealt with under the *Ministry of Environment Act* (B.C.), and the *Environment and Land Use Act* (B.C.) are important to water quality management in the estuary.

2.0 WATER QUALITY PLAN

2.1 Introduction

The Water Quality Plan has been designed to address the goals, objectives and policies of the Fraser River Estuary Management Program (FREMP Review Committee 1984). The purpose of the Plan is to establish Water Quality Objectives throughout the study area and to develop a coordinated monitoring program.

Key linked components of the Water Quality Plan are shown on Figure 4.

2.1.1 Overview

The Water Quality Plan begins with a review of information on sources and types of contaminants and a summary of principal estuary users. This provides background information for environmental assessment in the estuary and the establishment of Water Quality Objectives. A mechanism is proposed in the Plan for the development of federally and provincially agreed-upon Water Quality Objectives specific to the study area. Information on documentation required for establishing new objectives, compliance monitoring and actions where objectives are not achieved are given in the Plan.

A Recommended Monitoring Program is described in the Plan along with funding and/or staffing requirements and program coordination and implementation needs. The monitoring information generated will provide assessments of environmental quality and data on achievement of Objectives.

Requirements for Special Studies and Research beyond the scope of the routine monitoring program are reviewed in the Plan. Research information will provide more comprehensive environmental assessments and can be used to revise the Monitoring Program, improve regulatory standards and set more appropriate Water Quality Objectives.

The need for public involvement and participation is emphasized in the Plan. Similarly, interactions with FREMP Activity Programs and outside agencies and universities working in the estuary are essential.

The final section of the Plan provides an Implementation Strategy and outlines Plan costs. It assumes that the work will be undertaken by contractors, under the lead of a Plan Coordinator who reports to the Standing Committee or an equivalent Federal/Provincial body.

The Water Quality Plan and the Waste Management Activity Plan are intended to be developed in an integrated fashion. This will facilitate liaison and information exchange to ensure requirements for improved waste treatment and environmental monitoring are developed efficiently and effectively.

2.1.2 Sources of Pollutants in the Fraser River Estuary

Major sources of pollutant entry into the Fraser River Estuary are as follows (Waste Management Activity Program Working Group 1990):

1. municipal and industrial liquid waste discharges including stormwater and combined sewer overflows
2. non-point source discharges (e.g. landfill leachates and agricultural runoff)
3. dredging and dumping of sediments

4. upstream contaminant sources (natural and anthropogenic)
5. atmospheric inputs

These sources of pollutants can cause localized impacts or degrade large areas of the ambient estuarine environment (e.g. downstream transport of chlorinated organic compounds from pulpmill discharges in the upper watershed) (Kennett and McPhee 1988). In developing a comprehensive monitoring program, assessing the impacts of locally occurring contaminants as well as those which are widespread must be taken into consideration.

Table 2 and Figures 5-8 summarize the numbers and types of point source discharges into the Fraser River Estuary.

Following is a summary of the major contaminant sources and their importance for consideration in a monitoring program. More detailed information is presented in the FREMP Waste Management Activity Plan (Waste Management Activity Program Working Group 1990).

1. Municipal and Industrial Liquid Waste Discharges

Two municipal sewage treatment plants and a number of industries discharge effluents into the study area (Swain 1980; Cain and Swain 1980). The degree at which these discharges affect receiving water depends on the volumes discharged, the prevailing physical conditions (e.g. tidal cycle) (Churchland et al. 1982), dilution and the composition of effluents. It should be noted that a number of industrial operations discharge effluent via municipal sewage treatment plants, and that most industrial operations have industrial wastewater treatment plants on site.

Selected discharges typical of an industry (e.g. metal plating) require effluent characterization to determine the types of contaminants which should be included in the monitoring program for water, sediments and biota. Such discharges were studied in 1986 by MOE under an agreement with the Fraser River Harbour Commission (Supervisory Coordinating Committee 1987). Since industrial processes and types of industries discharging into the estuary change, an effluent characterization program similar to the 1986 study should be initiated every four to six years. Zone of influence monitoring in addition to that required by Provincial Waste Management discharge permits may be necessary if the effluents contain contaminants of concern or if they can cause toxic impacts.

2. Stormwater and Combined Sewer Overflows

Stormwater and combined sewer overflow discharges can occur at all times of the year. However, the peak discharges are related to high precipitation periods (i.e. winter months). High concentrations of certain contaminants and constituents of untreated sewage enter the river via these sources. MOE has carried out three studies to characterize stormwater discharges in the Lower Mainland (Clark and Krahn 1981; Swain 1983; Lawson et al. 1985) and Environment Canada (Krahn et al. 1987) and MOE (Supervisory Coordinating Committee 1987) have monitored concentrations of chlorophenols in stormwater entering the Fraser River from antisapstain operations. Monitoring of typical combined sewer overflows in each reach of the river is needed to provide information on toxicity, the volume and concentration of pollutants discharged and effects on ambient water quality.

3. Non-Point Source Discharges

Included in this category are agricultural runoff, uncollected landfill and woodwaste leachates, discharges from pleasure craft, shipping, discharges to ground, atmospheric deposition and groundwater inputs. Characterization of representative non-point sources is required as a guide for FREMP ambient monitoring. Where non-point source discharges are significant leading to concerns for protection of aquatic life, more detailed monitoring and remedial actions would likely be required.

4. Dredging and Dumping of Sediments

Dredging for the purposes of maintaining shipping channels and foreshore development frequently occurs in the Fraser River Estuary (Kennett and McPhee 1988). In addition, sediment dredged from the river or brought from outside sources is deposited in foreshore areas as fill for industrial developments if appropriate approval is gained. Because aquatic sediments typically are contaminant "sinks", the potential exists for the addition or redistribution of contaminants within the study area. A knowledge of areas of aquatic sediment contamination should be developed through the monitoring program. Some of these data have been summarized by B.C. MOE (Swain 1986; Swain and Walton 1988) and Environment Canada.

5. Upstream Contaminant Sources

With the exception of certain easily measured variables such as fecal coliforms and metals (B.C. Environment 1990), the contribution of contaminants from the river upstream of the study area is not well understood. Major industrial discharges such as bleached kraft pulp mill effluents enter the upper Fraser and Thompson Rivers (B.C. Environment 1990). This fact, in conjunction with numerous municipal, agricultural and non-point source discharges in the watershed, necessitates that river water entering the study area be well characterized in order to facilitate downstream impact assessments. The quality of Fraser River water entering the study area could be monitored under the terms of the Canada - B.C. Water Quality Monitoring Agreement. There are stations in the Fraser River Basin, at Hansard, Marguerite and Hope on the lower Fraser Main Stem, the Nechako River at Prince George and on the Salmon River. As an initial step, it is recommended that a Special Study be conducted to establish levels of toxic contaminants entering the lower river from upstream of the study area.

6. Atmospheric Inputs

The deposition of toxic chemicals from the atmosphere has been identified as a major input mechanism to the Great Lakes freshwater systems of Ontario (Beamish and Vanloon 1977) and Quebec (Environment Canada 1980) and may similarly be significant in terms of the Fraser River Estuary. A study in Portland, Oregon, which had lumber treatment operations similar to those of Greater Vancouver, showed that chlorophenate concentrations exceeded 100 µg/L in precipitation. Although the current levels in the Vancouver area are not known, it should be noted that chlorophenate use has been virtually eliminated in antisapstain treatment. In the Greater Vancouver area the GVRD operates a network of air sampling stations for measurement of ozone, nitrogen oxides, sulphur oxides, suspended particulates and, at some locations, total hydrocarbons and volatile organic compounds. Information is required on the importance of atmospheric inputs to the FREMP study area with regard to loadings of organochlorine pesticides, herbicides and wood protection/preservation chemicals.

2.1.3 Principal Water Uses and User Groups

Principal "user" groups which may be affected by poor water quality include people, aquatic life and wildlife. These groups and associated water uses were described in detail by the Working Committee on Fraser River Estuary Monitoring (1984); an updated summary is presented in Table 3.

Water Quality Objectives are limits set for physical, chemical or biological characteristics of water, biota or sediment to protect designated uses of waterbodies. Water Quality Objectives are based upon scientifically-determined data, known as Water Quality Criteria. The application of Water Quality Criteria on a site-specific basis, in relation to designated water uses and local conditions, leads to the development of Water Quality Objectives.

Water Quality Objectives directly or indirectly protect human users of water. In cases where Water Quality Objectives are determined for water column and/or sediment concentrations of a contaminant, indirect protection is provided through contaminant limits set for quantities of substances in edible biota. Water Quality Objectives which restrict concentrations of substances such as fecal coliforms in the water column result in the direct protection of human health.

Municipal and industrial uses of the estuary include dilution and assimilation of waste discharges. However, these uses do not require the maintenance of high water quality; rather, such usage must be controlled to ensure that other water uses are not impacted.

Fish, invertebrates and aquatic plants are included for protection under the designated use category of aquatic life. Water Quality Objectives, as defined in this Plan, are a management tool used to indicate whether the prevailing waste management practices are adequate to protect aquatic life from direct toxic effects of substances in the water column (e.g. ammonia) or in sediments (e.g. chlorophenols). The primary mechanism for protection of aquatic life is control of discharges at source. Water Quality Objectives are not applicable in initial dilution zones surrounding point source discharges (except in the case of objectives for fish flesh) (B.C. Ministry of Environment and Parks 1986). Where effluent quality standards are met, no acute toxicity should exist in initial dilution zones.

Wetland birds are protected under the category of wildlife. There is a general lack of scientific information specifically related to the effects of contaminants on birds and other wildlife (Butler and Campbell 1987).

2.2 Water Quality Objectives for the Fraser River Estuary

One goal of the Water Quality Plan is to provide a mechanism whereby specific Water Quality Objectives can be agreed upon by federal and provincial agencies and implemented for the study area. At present, provisional Water Quality Objectives (issued by the province) exist for the study area. Such objectives have been reviewed during their development by federal agencies. The process of Objectives development by MOE is continuing for other priority water basins in British Columbia.

Section 8 (1) of the *Canadian Environmental Protection Act* gives the federal Minister of the Environment the mandate to develop Water Quality Objectives. Therefore, a goal within FREMP is to develop a single set of agreed-upon Objectives that satisfy both federal and provincial mandates.

The FREMP Management Committee Executive has accepted as a starting point the provisional provincial Objectives titled, Fraser-Delta Area, Fraser River Sub-basin from Kanaka Creek to the

Mouth, Water Quality Assessment and Objectives (Swain and Holms 1985) and Fraser-Delta Area, Boundary Bay and its Tributaries, Water Quality Assessment and Objectives (Swain and Holms 1988). These Water Quality Objectives are included in Appendix II. In preparing Water Quality Objectives, the B.C. MOE recognized that uncertainties existed in Water Quality Criteria and water quality databases for local conditions. Thus, the Objectives are "provisional". In establishing new or revised Objectives for the Fraser River Estuary, larger databases are expected to be available to guide the process.

2.2.1 Mechanism for Development of Agreed-upon Water Quality Objectives

A mechanism to develop agreed-upon federal/provincial Objectives for the FREMP study area is shown in Figure 9. Any interest group or agency can propose new or revised Water Quality Objectives using this approach. Initially, the documentation for a Water Quality Objective is forwarded to the FREMP Standing Committee for the Water Quality Plan.

The Standing Committee could form an *ad hoc* subgroup (which may include outside experts) to review major issues as they arise, such as development of new or revised Objectives. An example would be the revision of Objectives for chlorophenols in sediments, which may need updating as new toxicity data are developed on fish and invertebrates. The subgroup would review the documentation and recommend a new or revised objective to the Standing Committee.

If a majority of the Standing Committee members agree with the initial proposal or the evaluation of the *ad hoc* sub-group, the recommendation and documentation for a new or revised Water Quality Objective would be forwarded to the FREMP Management Committee Executive for consideration. As an example of this cooperative process, certain water quality objectives have been agreed upon through FREMP for the Pitt River downstream of Pitt Lake (Swain 1989). The Standing Committee should attempt, but will not be required, to reach a consensus on issues prior to their submission. Only proposals receiving approval of the Management Committee Executive would be considered for publication by the Provincial Ministry of Environment.

2.2.2 Documentation for Development of Objectives

It is recommended that the documentation required to propose or revise a Water Quality Objective through FREMP should be similar to that required to prepare Provincial Objectives as outlined in Principles For Preparing Water Quality Objectives in British Columbia (Ministry of Environment and Parks 1986).

To develop or revise a Water Quality Objective for a particular characteristic in the Fraser River Estuary, information on some or all of the following will be required depending on the specific Objective being developed:

1. Water Quality Criteria. These values provide information on short-term (acute) and long-term (chronic) effects, persistence, accumulation in biota or sediment, antagonism or synergism with other substances and environmental fate of substances. Such criteria for fresh water are available in the Canadian Council of Resource and Environment Ministers (CCREM)[1] 1987 publication. Criteria information is also contained in documents prepared by B.C. MOE and the U.S. EPA, as well as in the general scientific literature. Some criteria

---

[1] Now known as the Canadian Council of Ministers of the Environment (CCME).

may be based on new information developed for the Fraser River Estuary or specific sites within it.

2. The existing environmental quality of the waterbody. This is defined by the physical, chemical and biological characteristics of the water, biota and sediment.

3. The temporal and spatial variability of the characteristic in water, biota and sediment.

4. The existing aquatic life in the waterbody and the potential for change as a result of the characteristic. This information includes species, geographic distribution, abundance, life history and commercial/social importance of aquatic life.

5. The flow or circulation pattern of the waterbody. This information would assist in interpreting ambient water quality.

6. The existing and potential impacts of the relevant contaminant discharges. This information would relate contaminant discharges to the quality of water/sediments and the apparent health of aquatic life.

7. The potential and existing uses of the water. This should include information on fish presence and utilization (spawning, rearing and migration of selected species) and other aquatic life, as well as recreational water use by people (e.g. swimming during summer months).

8. Other Considerations.

   The following additional information is recommended for inclusion in assessing the characteristic of concern.

a. Relevant water uses, waste discharges and ambient water quality monitoring sites should be plotted on maps of the appropriate scale to identify any cause-effect relationships. The nature and volume of the discharges should be described. Pertinent Waste Management Permit conditions such as effluent volumes, concentrations or loadings, treatment and monitoring required should be listed and effluent monitoring data should be summarized, wherever it is available.

b. Non-point sources of pollutants of concern should be shown on maps and their discharge volumes estimated. These discharges may include those from agricultural operations, mining, septic tank drainage, landfills, urban runoff, atmospheric deposition and boating, (i.e. any air, land, or water use activity that affects the aquatic environment). Any relevant surface water, groundwater or precipitation data should be summarized.

c. Dispersion of effluent containing the characteristic of concern should be described for the estuary.

d. Monitoring data relating to the characteristic of concern, including water, biota and sediment should be summarized. Data should be arranged by site and other spatial or seasonal characteristics, giving number of values, measure of variability, maximum, minimum and average, median, or geometric mean values. Water quality should be related to information on point and non-point sources of contaminants of concern where possible. Effects of the contaminant on water, sediments and aquatic life should be part of such an analysis.

e. The suitability of water quality for present and future water uses should be assessed by comparison with Water Quality Criteria. Water uses that can be supported by existing or improved water quality should be identified, and water uses that should be protected should be included.

f. A monitoring program should be recommended to determine whether the proposed Objective is being met.

g. A summary report based on the foregoing water quality assessment, including key findings, conclusions, maps of the area, and tables showing designated water uses, Water Quality Objective(s) and monitoring programs should be prepared. The report should be supported by an appendix with supporting data and references.

2.2.3 Objectives Monitoring

The provisional Water Quality Objectives of the Province of B.C., used as a starting point for the establishment of agreed-upon permanent Water Quality Objectives, have associated monitoring programs. The monitoring programs for Water Quality Objectives (in water) described below are not costed into this Plan because they are routinely conducted by the B.C. Ministry of Environment.

Monitoring should be conducted under worst-case conditions of high effluent loading and low river discharge. Achievement of the Objectives should be assessed through collection of samples at points 100 m downstream (or upstream under flood tide, low flow conditions) from the most significant point source discharges and assuming that, if the Objectives are achieved at these points, they will be achieved throughout the reach. Water quality should also be regularly assessed within 100 m of major point source discharges to verify dispersion assumptions.

The Objectives should be checked against five weekly samples in a 30-day period, because that is the minimum sampling frequency on which average concentrations for certain characteristics are based. More frequent sampling should occur where warranted based on site specific conditions.

Monitoring of the achievement of objectives has taken place since 1986. A number of objectives has been established, more than 12 of which are being met in 90% of samples (Rocchini 1987; MOE 1988; MOE 1989; MOE 1990).

2.2.4 Priority Issues for Objectives Development

Each of the agencies on the Standing Committee reviewed the monitoring and information needs for Water Quality Objectives in the light of their respective mandates. The committee agreed that the following information needs are sufficiently important to require action and funding ($300 k is allotted to Objectives development in Table 14 as part of the routine monitoring program). These are not necessarily listed in order of priority.

1. Using sediments and biota as integrating measures of accumulation, studies should be done (where required) to develop Water Quality Criteria and subsequently Water Quality Objectives for additional organic contaminants.

2. Aquatic toxicological information in the literature may be insufficient or not appropriate to describe estuarine conditions, species, or life stages of species. Where necessary, site-specific studies (e.g. bioassays and/or cause effect studies) using Fraser River biota should be carried out.

3. Many contaminants change in importance as industries change processes and their effluents are modified (Swain 1980). For example, such changes are expected with the elimination in use of chlorophenates in sapstain control in the sawmilling industry. It may be appropriate to develop Objectives for new antisapstain chemicals. This activity would require ambient monitoring but, because of sudden peaks of antisapstain runoff during storms and surface/shoreline contaminant plume formation, such monitoring needs to be carefully designed. Similarly there is a continuing need for data on polycyclic aromatic hydrocarbons (PAHs) as more information on their relationship to tissue abnormalities in benthic fishes becomes available (Mix 1986). Refinery effluents and other sources convey these compounds into many receiving waters (Swain and Walton 1989). More data are needed to determine if PAHs are at sufficient concentrations to be of concern in the Fraser River Estuary and whether Water Quality Objectives should be developed for those contaminants.

2.2.5 Attainment of Objectives

Objectives have no legal standing, thus compliance enforcement is not possible. Provisional Water Quality Objectives, except those for fish, do not apply within a distance of up to 100 m from effluent outfalls, that is within Initial Dilution Zones of effluent discharges (B.C. Ministry of Environment and Parks 1986; B.C. Pollution Control Board 1977; 1979; B.C. Department of Lands, Forests and Water Resources 1975; 1980; 1985). Waste dischargers are required to comply with Permits and Approvals issued by the Waste Management Branch, or Waste Management Plans approved by the Minister of Environment. In addition, Regulations under the *Fisheries Act* applicable to specific industry sectors establish enforceable effluent standards to protect fish in receiving waters.

The general provisions of the *Fisheries Act* prohibit discharges of deleterious substances into waters frequented by fish.

Information from ongoing monitoring will continue to be reviewed annually to determine the degree of attainment of Water Quality Objectives. Where Water Quality Objectives are not regularly attained, the issue will be brought to the attention of the Water Quality Plan Standing Committee as well as appropriate regulatory agencies for remedial and/or enforcement action. By these means, water quality problems theoretically will be addressed early and remedial action taken usually before legal action is initiated. As stated previously, the B.C. Ministry of Environment issues an annual report summarizing the attainment of water quality objectives province-wide. The Fraser River Estuary was included in reports for 1986 (Rocchini 1987), 1987 (B.C. Ministry of Environment and Parks 1988), 1988 (B.C. Ministry of Environment 1989) and 1989 (B.C. Ministry of Environment 1990).

Assessing whether Water Quality Objectives are being achieved is complicated by the temporal and spatial variability of water quality, and the occurrence of isolated high values that may be due to analytical or sampling error, natural events or waste discharge fluctuations. Several principles should be observed to reduce the difficulty of assessing compliance with Objectives as follows. The natural variability and extremes of water quality (e.g. freshet) (B.C. Ministry of Environment and Parks 1986) should be considered when establishing Objectives. Monitoring frequency should be sufficient to allow statistical evaluations to be carried out. Both upstream or control sites and downstream or test sites should be monitored simultaneously when possible to account for natural influences on water quality. In addition, waste discharges should ideally be monitored coincident with receiving water to determine their influence on water quality. All sampling programs should follow strict protocols of sampling and quality assurance (QA). Quality Assurance and Quality Control, often referred to together as "QA/QC", are those portions of a monitoring program which ensure that the data reported are reliable and meaningful. Quality Control, or "QC", is primarily concerned with the routine application of procedures to produce high quality data. For example an analyst might check that an instrument is functioning correctly by running various calibration samples, methods blanks and spiked samples through the instrument. Quality Assurance, or "QA" is concerned with all aspects of maintaining data reliability but is especially concerned with independent tests of accuracy and precision through analyses of replicates and standard reference samples. To distinguish between QC and QA, consider that usually the analyst knows exactly what results are expected for QC samples but often is completely unaware of the expected results for QA samples. "QA/QC" and "QA" often are used as synonyms.

2.2.6 Interim Criteria and Guidelines

It is recognized that Water Quality Objectives are not yet developed for certain substances. Accordingly, the following reference documents are useful for review:

1. Water Quality Criteria documents prepared by MOE for use in British Columbia. (See Appendix V)

2. CCREM Task Force on Water Quality Guidelines. 1987. Canadian Water Quality Guidelines.

3. PTI Environmental Sciences. 1987. Policy Implications for Effects-Based Marine Sediment Criteria.

4. Tetra Tech Inc. 1986a. Development of Sediment Quality Values for Puget Sound.

5. EPA documents on water quality criteria. (See Appendix V)

2.3 Recommended Monitoring Program

2.3.1 Introduction

The main goal of the monitoring program is to provide information on the health of the estuary and indicate areas where improvements are required. Accurate determination of changes in aquatic environmental quality requires a comprehensive database on physical, chemical and biological conditions and detailed information on pollutant discharges. Government agencies need sound environmental quality information to effectively manage aquatic resources in the Fraser River Estuary. The identification of long-term trends in contaminant levels in the estuary through ambient monitoring and the assessment of specific problem discharges through compliance monitoring provide a measure of the effectiveness of estuary management programs and regulatory activities. Information resulting from problem-specific studies increases the capability of agencies to evaluate results of environmental quality monitoring.

This section of the Water Quality Plan recommends a coordinated monitoring program to address these management needs. The program is based upon Fraser River Estuary Monitoring - A Recommended Approach (Working Committee on Fraser River Estuary Monitoring 1984) with modifications to reflect current environmental concerns and management priorities. As designed, the program will provide for accurate assessment of ambient environmental quality throughout the study area, including monitoring to determine whether Water Quality Objectives are being met. In addition, the monitoring program includes Special Studies to provide additional information on impacts of pollutants.

Provision is made for monitoring of low velocity sidechannels and sloughs. Data generated will be used to evaluate present conditions and where necessary establish more definitive Water Quality Objectives. In addition, future monitoring programs and possible legal and mitigative actions could be initiated based on monitoring results.

2.3.2 Program Goals

1. To determine the current status of ambient environmental quality in the estuary and trends over time.

2. To obtain additional data on environmental quality in low velocity sidechannels and sloughs where environmental extremes may be expected to occur.

3. To identify areas of degradation where actions such as abatement, enforcement, restoration, habitat improvement and research may be required.

4. To provide information for the formulation of new Water Quality Objectives and the revision of existing Objectives if necessary.

5. To monitor selected effluents periodically to ensure that the ambient data collection program is well directed.

2.3.3 Ambient Monitoring Program Development Guidelines

Monitoring for ambient conditions will be conducted at an upstream reference site outside the study area and within the study area in the main river channels, major tributaries, backwaters and sloughs, and on Roberts and Sturgeon Banks and in Boundary Bay.

Such monitoring will promote better understanding of spatial distribution and fate of selected contaminants. Where possible ambient monitoring will include water, sediments and biota, which will be collected from the same location to enhance correlation. Agreed-upon protocols for sample collection, analyses and data management will be prepared and adopted to provide comparable data for spatial/temporal trend analyses. The following are key aspects of the program.

1. Selected effluent discharges will be sampled to aid in the selection and addition of contaminants for ambient monitoring. This sampling will be carried out at times when waste concentrations or loadings are highest as well as during normal operating periods. Such monitoring is in addition to any data collected under specific provincial Waste Management Permits. The selection of effluents to monitor will depend upon a review of individual industrial and municipal operations and a general knowledge of effluent quality.

2. Water quality monitoring will be carried out at a reference site upstream from the study area to establish background concentrations and loadings. Ambient monitoring in the study area will be conducted in the North Arm and Main Arm. Monitoring should be done over a tidal cycle at pre-freshet low flow (spring) and autumn first flush. Costs for monitoring of water include selected organic contaminants such as chlorophenols and resin acids. Specific methods development for organic contaminant analyses in water has been placed in the Special Studies category.

3. Monitoring of surface bed sediments is required to identify areas of pollutant build-up in relation to sediment Objectives (Swain and Holms 1985). Monitoring

of sediments will be conducted at reference and study sites under pre-freshet, low-river flow conditions in late winter (before a new sediment load is deposited) such that worst case contaminant concentrations can be monitored (Working Committee on Fraser River Estuary Monitoring 1984). Particle size, volatile residue, metals and those organic contaminants identified for effluent monitoring will be analyzed in surface sediments.

4. Invertebrate sampling at reference and study sites should be conducted during pre-freshet, concurrent with sediment sampling due to the potential for sediment ingestion and bio-uptake (Working Committee on Fraser River Estuary Monitoring 1984). Monitoring of biota should focus on selected resident species to allow spatial comparison. Contaminant analyses should address chemicals identified in effluent and sediment that are. toxic, persistent and/or bioaccumulative.

5. Although Swain (1986) reported minimal success in collecting fish during the pre-freshet January/February period when sediments and invertebrates were collected, recent work by DFO (1989) and earlier studies (DFO 1981) showed fish were readily taken mid-March to early April from sloughs and some main channels by beach seining, trapping and angling. Fish should be collected at control and study sites used in previous studies (Northcote et al. 1975; Singleton 1983; Swain and Walton 1989). Both muscle and liver tissue of fish should be analyzed (Swain and Walton 1989). Where small fish are collected and dissection is not possible, analyses should be performed on the whole body.

6. Sloughs and similar low water velocity backwaters should be monitored at frequent intervals. Particular attention should be given to the period prior to freshet. Adverse water quality conditions, including lethal and stressful levels of dissolved oxygen, can occur (from natural and man induced causes) in poorly flushed areas at times of low freshwater flow and high saline intrusion (Kennett and McPhee 1988). In addition, monitoring of sloughs should occur on high slack tidal conditions at deep water sites (Swain and Holms 1985). Sites should also include shallow shoreline areas which may be utilized by fish.

2.3.4 Guidelines for Special Studies and Research

The Standing Committee has developed a list of Special Studies which are not included in the routine monitoring program but which are required to address specific environmental problems within the estuary, quantify impacts on fish from specific effluents and establish Water Quality Objectives. To assign a study to this category, one or more of the following criteria should be met:

- studies suited to an intensive sampling approach over a short time period, as opposed to the infrequent sampling and long-term approach of the routine monitoring program;

- studies addressing improving monitoring methodology;

- studies aimed at linking cause and effect, such as controlled exposure trials in the laboratory coupled with field sampling of body burdens; or

- studies assessing effects on fish of interactions between dissolved oxygen and selected pollutants or effluents.

2.3.5 Existing Monitoring Programs

The Standing Committee reviews monitoring and research throughout the estuary and has sponsored four annual workshops on this topic. Reports produced to date (Standing Committee 1987; 1988; 1989; 1990) summarized the types of ongoing investigations and provided more opportunity for coordination of effort.

The first Summary of Research and Monitoring identified thirty-two studies relating to the estuary (Standing Committee 1987b). These studies included toxicity assessments and addressed monitoring of metals and organic contaminants in one or more environmental compartment (i.e. effluent, water, sediment and biota) in most areas of the estuary. Twelve of the thirty-two studies involved sediment sampling, 19 involved water, 10 included sampling of biota and 6 were bioassay studies. No overlap in monitoring/research programs was identified in that review. The studies addressed a variety of questions and differed with respect to timing and location of sampling and to the environment compartments and/or contaminants monitored.

Some existing programs vary from year to year, while others are consistent and long-term in nature. It is evident that some ongoing monitoring programs can be incorporated into the FREMP Recommended Monitoring Program. Adjustments to sampling and analytical protocols may have to be made as discussed in the following section.

2.3.6 Recommended Ambient Monitoring Program

The monitoring program presented in this document is modified from that presented in the report Fraser River Estuary Monitoring - A Recommended Approach (Working Committee on Fraser River Estuary Monitoring 1984) such that the frequency of sampling has been increased and new developments in water management (e.g. Water Quality Objectives, Swain and Holms 1985) have been reflected. The time frame for monitoring has been compressed to provide more frequent data collection. The program operates on a three-year cycle, with sampling occurring throughout the study area for each environmental compartment. The proposed three-year cycle, operating on a fiscal year basis (April to March), is as follows:

YEAR 1
- Effluent and water sampling, chemical analyses and data interpretation.
- Half of the effluent discharges identified for monitoring will be done in Year 1 and the remainder in the first year of the next cycle. This produces a 6-year cycle for examining effluents except that the 2 major sewage treatment plants are investigated in each 3-year cycle.

YEAR 2
- Sediment and invertebrate sampling during pre-freshet period. (February/March)

- Water sampling and analyses
- Sediment analyses from Year 1

YEAR 3
- Fish sampling during late pre-freshet period (early April) and analyses
- Invertebrate analyses from Year 2
- Water sampling and analyses
- Data interpretation and reporting for the current three-year cycle (Report writing to continue into the first year of the next cycle)

A summary of the monitoring program appears in Table 4. The number of sampling sites and replicates are given in Table 5 with monitoring locations identified on Figure 10.

2.3.6.1 Protocols for Sampling and Quality Control/Quality Assurance

It is essential that sampling and analytical protocols be developed for the proposed monitoring program. Regardless of who carries out the work, adequate Quality Assurance/Quality Control is required both in the field and in the laboratory. Appendix IV provides an outline of the minimum QA/QC requirements for the different aspects of the monitoring program. To increase the comparability of data with previous studies and monitoring, the Standing Committee recommends that, where possible, protocols be selected or developed from the following reference documents.

1. Methods of Aquatic Data Collection in British Columbia: A Catalogue (Clark and Shera 1985).

2. A Laboratory Manual for the Chemical Analysis of Waters, Waste-waters, Sediments and Biological Tissues (McQuaker 1976).

3. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (Tetra Tech 1986b).

4. Sampling and Analysis in the Arctic Marine Benthic Environment (Arctic Laboratories 1985).

5. DOE/DFO Environmental Laboratory Manual. 1979.

6. Standard Methods for the Examination of Water and Wastewater (latest edition).

7. Applicable U.S. EPA approved methods.

8. Active protocols of the QA Work Group to the Canada - B.C. Water Quality Monitoring Agreement. M. Clark (ed.) 1990.

2.3.6.2 Effluent

The report, Fraser River Estuary Monitoring - A Recommended Approach (Working Committee on Fraser River Estuary Monitoring 1984) proposed that effluents from key industrial and municipal facilities be investigated to set priorities for subsequent monitoring as required. The purpose of the investigation was to identify contaminants which may not have been monitored in the estuary.

During the 1986/87 fiscal year, the B.C. Ministry of Environment and Parks conducted the first year of the monitoring program (largely as outlined in the 1984 report) through agreement with the Fraser River Harbour Commission and with assistance from Environment Canada. The program's main findings are overviewed in the Summary Report of the 1986 Effluent Monitoring Program (Supervisory Coordinating Committee 1987). Twelve sites were investigated with detailed assessments at eight industrial sites and less intensive assessments at three municipal sewage treatment plants and at a sawmill practising sapstain control. A similar approach is recommended in future programs.

Recommendations from the 1986 program which are pertinent to the current Water Quality Plan are as follows:

1. GC/MS analyses should be conducted on composite effluent samples at least once every three years at all sites investigated to determine existence of trace organic contaminants.

2. The program's budget should include a salary and expenses component for contract staff.

It is recommended that future effluent monitoring programs be conducted on a three-year cycle. Effluent discharges associated with three categories of operations will be monitored in the current program (Table 6), as follows. The first category, to be investigated every three years, includes the two sewage treatment plants, at Lulu Island and Annacis Island. These discharges have been priorized because of their high effluent volumes and toxicity of the effluents to fish (Singleton 1980), as shown by regular monitoring. Although the Greater Vancouver Sewerage and Drainage District conducts analyses for contaminants in effluents from STPs, there is a need for further characterization of effluent trace organics. For these analyses, flow proportional composite samples should be collected and GC/MS analyses carried out on selected samples to confirm trace organic content (Supervisory Coordinating Committee 1987). Sampling to determine the worst-case effluent quality should be conducted to characterize extremes discharged into receiving waters.

The second category of operations to be investigated includes industries of high priority based on discharge volume and likely presence of contaminants of concern (Swain 1980). It is recommended that half of the total list of such operations be investigated every three years (i.e. six years to complete the list) using flow proportional composite sampling techniques. Only one-half the list is to be examined every three years because the nature of industrial operations is such that their processes will not change significantly through time. Should these industrial processes change, a modification to the company's Waste Management Permit would be required. Another reason for selection of this frequency of monitoring is that routine monitoring for all permits is generally required as a condition of a Waste Management Permit.

The third category includes operations which are perceived to have comparatively minor environmental impacts. It is important to investigate two or three of these every three years because an overall goal of the program is to provide assurance that unforeseen contaminants are not being discharged. Composite samples should be collected for analysis.

2.3.6.3 Water

2.3.6.3.1 Objectives

The objectives of the water chemistry monitoring program are to determine trends at downstream sites and to determine loadings, concentrations and trends of contaminants and other parameters entering the study area at an upstream reference site. Sloughs and sidechannels are important fish habitat and may be vulnerable to environmental extremes due to poor flushing, stagnation effects and possible low dilution of wastes in the water. Water column monitoring will also be carried out in these areas to assist in the assessment of environmental conditions.

2.3.6.3.2 Main River Sites

The characterization of water quality in tidal estuaries is made difficult by changing river velocity and salinity, multiple dosing of effluents and diurnal patterns in effluent discharge, variability across the river (and with depth), and seasonal differences in temperature, suspended sediments, and other variables (Churchland et al. 1982; Hall 1985). However, Lawson et al. (1983) have shown in a study conducted at the Pattullo Bridge that considerable variability was evident only at boundary conditions (i.e. at the shore). In order to avoid the effects of boundary conditions it is recommended that monitoring be carried out at mid-stream and a depth of one metre. It is recognized that different conditions will exist vertically in the water column, however, this depth has been chosen for the purpose of consistency and to ensure that riverine water is characterized. Furthermore, in order to minimize the impact of variability due to tidal influences, it is recommended that the monitoring be carried out at low slack tide. Bi-weekly monitoring is recommended in order to provide sufficient information to characterize sites in spite of inherent variability. To assess variability in the cross section of the river, five sites across the channel (including the high frequency site) will be sampled quarterly. Sampling sites are recommended in the North Arm near the Oak Street Bridge and in the Main Arm near Tilbury Island.

In order to characterize the chemistry of the water entering the FREMP study area a site near the Environment Canada gauging station near Mission should be used. The site should be sampled twenty-six times per year.

Inorganic variables to be measured at main river sites (including the upstream reference site) include: temperature, pH, conductivity/salinity, alkalinity, hardness, non-filterable residue, filterable residue, nitrate/nitrite, ammonia total Kjeldahl nitrogen, total and dissolved phosphorus, and total organic carbon. Other variables to be measured are fecal coliforms, total mercury and total and dissolved; cadmium, copper, lead, nickel, zinc, and chromium.

It is recognized that some monitoring for organic chemicals in the water column should occur. Organic variables to be measured include: chlorophenols (and other wood protection/preservation chemicals such as TCMTB), resin acids, guaiacols, catechols, selected pesticides and nonylphenol. At the present time, the final design of the organic monitoring program is dependent upon the completion of a special study which would be used to determine the frequency of monitoring for the organic chemicals listed above.

2.3.6.3.3 Sloughs and Sidechannels

Sloughs and sidechannels, due to low water velocity, are included as sites for the water chemistry monitoring program to attempt to characterize environmental extremes in the waterbodies. Ladner, Deas and Gundersen sloughs are recommended for sampling in the Main Arm, McDonald and Tree Island sloughs and a site immediately west of the Arthur Laing Bridge are recommended for sampling in the North Arm (Figure 10). Monitoring will be conducted at low pre-freshet flow and autumn first flush. Sampling will be done at high slack tidal conditions one metre below the surface, and one metre above the bottom. Variables to be measured will be the same as those for the river sites with tests for organics limited to the autumn, first flush sampling period.

2.3.6.4 Sediments

Sampling should include shallow intertidal sediments on Roberts and Sturgeon Banks and Boundary Bay. Sediment sampling will also be conducted in selected slough areas, main channels and tributaries of the study area (Figure 10). The recommended sampling period is early spring, pre-freshet. This timing should reflect maximum sediment contaminant accumulation, prior to deposition of a new seasonal sediment load during freshet (Milliman 1980). The timing is designed to allow the chemical analyses to be done in the same or the following fiscal year. In collecting sediment samples, the surface 2 cm is used for the analyses (Milliman 1980). Five replicates are to be collected at each site, with analyses conducted for sediment volatile residue, particle size, metals, organic contaminants (PCP, TTCP, TCP, PCBs, dioxins, furans, guaiacols and PAHs) and TOC. In each monitoring program cycle the list of contaminants will be reviewed to determine whether changes are required. Swain and Walton (1988) collected ten sequential replicate sediment samples from the six sites recommended in this Plan. The sequential samples were examined in the order that they were collected to determine if a smaller effort (i.e. fewer samples) could provide the same information with equal statistical confidence. It was determined statistically ($p = 0.05$) that nearly 95% of the characteristics measured (metals, phosphorus, carbon) were explained equally in terms of variability (F-test) and similarity of mean concentrations (Students t-test) by three sediment samples as with ten. The remaining characteristics (barium at site NA-2, Figure 10, strontium and phosphorus at site NA-1, and total carbon at site MS-1) could be explained by using four replicates, or, in the case of phosphorus at site MA-1, five replicates. When values of some of the replicates were below the detection limits, such as for mercury and lead, it was not always possible to determine the required number of samples. Notwithstanding, Swain and Walton (1988) showed that three replicate sediment samples provide 95% confidence; whereas five replicate samples improve that confidence level to near 100%. The associated cost increment is a 67% increase (by going from 3 to 5 replicates).

2.3.6.5 Biota

Biological monitoring provides information on bioconcentration of contaminants. Biota recommended for sampling are to include resident (and if available, migratory) species of fish and invertebrates (Table 8).

It is recommended that fish sampling be conducted in the early April pre-freshet period utilizing beach seining, gill netting, minnow trapping and angling. Sampling of invertebrates is best conducted during the pre-freshet period concurrent with sediment collection (Swain & Walton 1988). With such timing it may be possible to relate water and sediment contaminant levels to those found in the biota.

Mysid and amphipod species exist throughout the study area (Northcote et al. 1976). This factor and their ease of sampling and abundance make these taxa the favoured invertebrates for monitoring. Crabs and bivalves are recommended biota for monitoring on Roberts and Sturgeon banks and in Boundary Bay. Muscle tissue from crabs and bivalves, plus crab hepatopancreas should be analyzed for contaminants (Oehme et al. 1990).

Several species of resident fish of interest in a monitoring program are present in the study area (Table 8). Ideally fish species should be resident throughout the study area to permit spatial comparison. Fish should be of sufficient size to allow muscle and liver tissue to be analyzed separately. The fish collected will be weighed, measured, and, if possible, aged and sexed. Life history information relating to the movement of key species (e.g. starry flounder) in the estuary should be improved as is recommended in the Special Study Section (2.4).

In addition to the use of resident species of fish for assessing trends in contaminant burdens, a fish species which migrates through the estuary to spawn should be sampled. The lipid-rich eulachon is an anadromous fish which may accumulate organic contaminants as it migrates through the estuary prior to the start of spring freshet (Higgins et al. 1987).

Five muscle and liver samples of each fish species should be analyzed for lipid content, percent moisture, metals, chlorophenols, dioxins/furans, guaiacols, PCBs and PAHs. As in the case of sediments, parameters measured will be reviewed annually and based upon results, necessary changes would be made to the program. If fish are too small to dissect, whole body samples should be used. All organisms of a given species should be of a single size class.

Fish histopathological data may be useful as a means of assessing potential water quality degradation (Myers et al. 1987). Recent studies conducted near Sturgeon and Roberts Banks showed the existence of skin lesions in flatfish; other studies (Goyette and Boyd 1987) elsewhere have documented sole liver lesions (i.e. in Burrard Inlet). Accordingly, it is recommended that bottom fish, (twenty replicates) be examined for the presence of epidermal and liver lesions.

For invertebrates, amphipods and mysids (where quantities allow) will be analyzed on a whole body basis for the above noted variables with the exception of dioxins/furans and guaiacols. Crab muscle and hepatopancreas will be analyzed for metals, chlorophenols, dioxins/furans, guaiacols, PCBs and PAHs.

Swain and Walton (1991) have reported on toxicity tests performed at three sites in the Fraser River (MS-1, MA-2, and NA-1) and one site in Boundary Bay (BB-1). For each site, the sediments were tested using the total sediment sample, sediment in the particle size range from 0.063 mm to 2.0 mm, and sediment particles sized <0.063 mm. Initially, the sediments were "leached" using a modified Special Waste Extraction Procedure where sea water was used to "leach the sediment. Two toxicity tests, the Microtox EC50[2] and the sand dollar FID50[3] with three replicates at each site were used for each size fraction (18 tests per site). Both tests for all the replicates in the three Fraser River sites were non-toxic; two of three tests for the particle size range from 0.063 mm to 2.0 mm had some toxicity for the sand dollar test, and one of the three samples for sediment particles sized <0.063 mm had some toxicity for the sand dollar test. Some toxicity testing of sediments at the Boundary Bay site should be continued when sediment chemistry is measured.

---

[2] EC50 is the effective concentration of test substance that causes 50% reduction in light output from a light emitting bacterial culture used for toxicity testing.

[3] FID50 is the concentration of a substance or chemical compound that causes a 50% reduction in egg fertilization after a 10 minute exposure.

The Canadian Wildlife Service (CWS) is collecting eggs from the great blue heron colony at Roberts Bank for mercury, selected pesticides and dioxin analyses. Therefore FREMP will have no additional requirements for heron egg collection.

2.3.7 Data Management, Interpretation and Reporting

Data collected in the various initiatives of the monitoring program should be accompanied by the relevant QA/QC data. Regardless of who carries out the work, data should be stored on a microcomputer to facilitate transfer to members of the Standing Committee or their agencies. Requests from other interested parties for access to the information prior to publication would be made to the Standing Committee. Experience has shown that very few requests for data can be expected, and therefore, the cost of a separately managed database cannot be justified at this time. Since most of the agencies now use microcomputers extensively, the proposed system represents minimal cost to the member agencies for data management. At most the expenditure by each agency of a few hundred dollars for a modem and one of the more common database software packages would be required.

The FREMP monitoring program has been designed to be repeated every three years. At the outset of the program, priority must be given to establishing the protocols for sampling, analysis and data handling. In the first year of the cycle, effluent and water quality data would be reviewed and compared against permit limits and Water Quality Objectives, respectively. A summary report would be prepared.

In the second year, effluent and water chemistry analyses and data interpretation would continue, followed by report preparation. Finally a summary report would be prepared comparing contaminant levels to effect levels, where available.

Interpretation of water quality data would continue in the third year in addition to analyses for sediments, invertebrates and fish. Summary reports would be produced for each component, comparing contaminant levels to impact levels where these are known. Overall interpretation for the current three-year cycle would begin by the summer of the following year.

Preparation of yearly summary reports will allow modifications to the program and recommendations for remedial action to be made by the Standing Committee before the end of a three-year cycle. The Standing Committee, with the assistance of the study coordinator, is responsible for review of monitoring program results, program modification, preparation of summary reports and a monitoring program report.

2.3.8 Program Priorization

The terms of reference for the Standing Committee require the monitoring program to be priorized with regard to site location, environmental compartment and effluent and receiving water characteristics monitored.

The FREMP monitoring program has been designed as the minimum program necessary to produce the degree of information required to estimate trends in receiving water contamination with statistical confidence and to assist in formulation of new/revised Water Quality Objectives.

The proposed monitoring program is focused on assessing the degree of contamination in receiving water and biota. Should resources become available, priority in future years should be given to work to address possible effects on biota associated with known contamination.

2.3.9 Funding and Personnel Requirements

It should be noted that funding for the program has not yet been approved. Time estimates for field personnel in the FREMP monitoring program are shown in Table 9. Included in those estimates is the time necessary for specialized technical personnel (e.g. engineers, biologists and technicians) to assess in-plant operations, collect effluent and ambient samples and prepare them for analyses.

The monitoring program analytical cost estimates presented in Table 10 have been derived using prices which Environment Canada chemistry laboratories charge in 1990 to external users. These costs approximate those of private laboratories. The approach taken above provides estimates of maximum program costs for contracting all analytical requirements. Additional resources - personnel and funding - would likely be required by government laboratories to accept the added analyses associated with the FREMP monitoring program.

Monitoring program cost estimates have been broken down on the basis of year, environmental compartment and general location within the estuary (Table 10). This costing of different phases of the program provides a detailed summary of funding requirements.

The cost breakdown and priority ratings will provide guidance in allocating resources. The analytical costs of the three-year Recommended Program (including routine QA/QC) are estimated to be $1,354,000 (Table 10).

A nonroutine quality assurance/quality control (QA/QC) program is an essential part of the overall program. Fifteen percent of field analytical and data analysis costs or approximately $250,000 should be made available for nonroutine QA/QC. Additionally, a full time QA/QC officer should assist the study coordinator and take responsibility for the overall quality control of the program.

Total cost estimates for the monitoring program (sample collection, chemical analyses, QA/QC, data interpretation and reporting) are given in Table 11. In addition to the costs for sample analysis and QA/QC, an estimated $65,000 for contract support will be required over the three years for data analysis and interpretation and $65,000 for report preparation and publication. Inflation is expected to increase the cost by approximately 10% per annum.

2.3.10 Monitoring Program Coordination and Implementation

2.3.10.1 Coordination

The monitoring program will be interfaced closely with existing monitoring and research activities to ensure effectiveness, efficiency and no duplication of effort. Universities, industry, municipal governments and federal and provincial agencies are expected to provide data in addition to that collected through the Water Quality Plan. A summary of the roles of the numerous agencies which have conducted water quality work in the estuary is contained in Appendix III. Additionally, the program will be closely linked with other FREMP committees such as the Waste Management Activity Group.

The coordination of monitoring and research activities in the Fraser River Estuary is intended to be a responsibility of the FREMP Standing Committee. The annual workshop on Fraser River research and monitoring sponsored by the FREMP Standing Committee is a valuable co-ordinating mechanism and will be continued. Potential program duplication and areas for cooperative studies can be identified and investigators brought together. Through the review by the Standing Committee, research needs and information gaps in the ambient monitoring and fisheries programs can be identified for action by researchers and/or funding by FREMP. With the recommended three-year cycle for monitoring of environmental compartments, timely modifications to the monitoring program can be made based on data collected and evolving priorities.

2.3.10.2 Implementation

The Standing Committee recommends that, because of the magnitude of the proposed FREMP water quality program, the program should be carried out through a Plan Coordinator reporting to the Standing Committee or equivalent federal/provincial body. The Plan Coordinator should be supported by a QA/QC Officer, responsible for ensuring the quality of the data through the development of protocols for all aspects of sampling, analysis and data handing, and the ongoing quality control audit of the program. The Plan Coordinator and the QA/QC Officer could either be person years which may have to be added to the complement of the participating agencies, or contract employees. It is assumed that the work of the monitoring program itself would be carried out using contract funds, or through a combination of in-house resources and contract funds.

The recommended monitoring program presented in this report should be initiated in November 1991, with the Plan coordinator and QA/QC officer hired by May 1, 1991. Such timing will allow for the development of protocols for sampling, analysis and data management, to ensure efficient implementation of the monitoring program. Until the FREMP monitoring program is finalized, the sampling begun under FRES should continue. This sampling will become a component of the FREMP program.

Although a number of ongoing responsibilities associated with the monitoring program (e.g,. report writing) are assigned in this document to the Water Quality Standing Committee, in future report preparation and publication should be conducted by the Plan Coordinator. The Standing Committee would be responsible for reviewing and approving draft reports and approving changes to the monitoring program where appropriate.

2.4 Required and Suggested Special Studies

Although the routine monitoring program described herein includes a systematic protocol for data collection with strong emphasis on assessing contaminants in water, sediments and biota, it does not include studies that are needed to provide specialized information. The Plan makes reference to a number of Suggested Special Studies that would address such information gaps. It is essential, however, that Required Special Studies, identified annually by the Standing Committee, be conducted through the FREMP monitoring program. Examples of Required Special Studies include measurement of organic contaminant loadings entering the study area from upstream; and the ongoing identification of new contaminants in the estuary.

The Suggested Special Studies are briefly described in Table 12 along with agencies most appropriate to administer a specified study. It should be noted that the presence of an agency name with a study does not imply a commitment to conduct the project, but rather an area of expertise.

Table 14, which provides a breakdown of the program costs, shows provision for Required Special Studies under Non Routine Monitoring. As Table 14 indicates, Suggested Special Studies should be funded outside of FREMP as Priority II. In addition, a University Chair in aquatic environmental toxicology is recommended as Priority II. Estimates of the costs for the latter two programs are outside the scope of this plan. The field of aquatic toxicology has been chosen for the University Chair because such a position would generate interest supporting the development of water quality objectives and associated impact assessments. Suggested Special Studies, which are well suited for implementation via contract or through specific agency programs outside the routine FREMP monitoring program are recommended for funding in the near future. Some of the above studies were recommended in the 1984 FRES report (Working Committee on Fraser River Monitoring 1984).

2.5 Pollution Related Enforcement Procedures

Enforcement procedures under environmental legislation are under review through Federal and Provincial agencies. The documentation of agreed-upon enforcement procedures referred to in the terms of reference of the Standing Committee was carried out by the Waste Management Activity Program of FREMP.

2.6 Public Education and Involvement

The Standing Committee supports education programs prepared by the member agencies (Harvey et al. 1982) that are in the spirit of protecting the environment and the estuary. One such program is the Storm Drain Marking Program of the B.C. Recreational Fisheries Branch and the Salmonid Enhancement Program. Commonly called the "Yellow Fish Program", this educational effort has two direct benefits:

1. When storm drains which discharge to streams are marked on the street with the symbol of a fish, it prevents most

individuals who would otherwise dispose of waste in the storm drains from doing so.

2. The program is generally carried out by children through such organizations as the Girl Guides and the Boy Scouts. This promotes environmental awareness in children at an early age.

Public information brochures on proper disposal methods for hazardous and toxic waste have been put out by the Province of British Columbia as well as by the GVRD as part of its Liquid Waste Management and Solid Waste Management plans and these brochures have been beneficial in protecting the environment and the estuary. Member agencies are encouraged to continue reprinting this type of information and distributing it as widely as possible to the public.

FREMP is encouraged to use the brochure approach to promote its own educational goals. Educational brochures on such subjects as habitat protection could be produced through the FREMP office for general public distribution. The Water Quality Plan Committee should produce a report card type brochure on the status of environmental quality in the Estuary (either directly or through the Plan Coordinator) coincident with the more comprehensive Status Report at the end of each three-year cycle. This could be done each year once the monitoring results for that year are available. The brochure should be widely distributed to the public through libraries and schools and be available in the offices of all member agencies. The Status Report should be distributed to all public libraries and higher educational institutions.

Education can also be provided to the public through the following means:

1. Annual presentations on the status of water quality and research and monitoring activities at a central location such as Robson Square at a convenient time (e.g. evening sessions).

2. A comprehensive video or slide tape should be produced explaining FREMP and different aspects of protecting the environment. The tape could be updated as required. Free copies of the tape should be distributed to every school in the region starting at the elementary school level. In addition, copies should be available for loan from every member agency office and the FREMP office.

3. FREMP should work with the B.C. Ministry of Education to produce an education package on environmental protection that students could work through at a young age. The package should be comprehensive in nature and highlight everyday activities that can lead to pollution of the environment and the estuary, and how those activities can be altered to protect the environment.

The FREMP office should encourage public involvement programs such as Citizen Patrols or Adopt a Stream/Adopt a Beach type programs.

Of the public education and involvement initiatives outlined above, those most likely to be handled by the Standing Committee would be the production of "report card" type brochure on the status of environmental quality in the estuary, and hosting of an annual public meeting/workshop on environmental quality. It is anticipated that the budget requirements for these two initiatives would be approximately $60,000 every 3 years. The Water Quality Plan Standing Committee would be available to contribute to the production of a video presentation for distribution to schools, public interest groups, etc. However, it is assumed that this type of initiative would be directed and funded through the FREMP program in general.

2.7 Interactions With Other FREMP Activities

The Standing Committee for the Fraser River Estuary Water Quality Plan interacts with the Activity Programs under FREMP in two ways: by commenting on water quality issues raised in such programs and by initiating discussions with Activity Programs on topics of mutual concern. The first interaction needs little discussion, since it will most often involve providing advice as required or recommending to the FREMP Management Committee Executive that specific actions be taken.

The second type of interaction will likely originate when ambient monitoring data show Water Quality Objectives are not being achieved and/or environmental impacts from specific discharges have occurred. If Water Quality Objectives are not being achieved, the preferred option would be that the FREMP Standing Committee would notify the appropriate FREMP Activity Program (Figure 2, e.g. Waste Management Activity Program), and review suspected sources of the problem. It will then be the responsibility of the Activity Program to work through its member agencies to achieve remediation. A "lead agency" would need to be identified from within the Activity Program to deal with the problem at source and to provide feedback to the Standing Committee. The Standing Committee will also provide advice through the FREMP Management Committee Executive to the lead agency regarding achievement of Objectives.

The Standing Committee would not routinely interact with the Environmental Review Committee (ERC). However, members of the Standing Committee could possibly have roles as project reviewers for respective agencies on the ERC. The Standing Committee responds to questions on water quality from the Environmental Review Committee and the FREMP Activity Programs.

3.0 PLAN IMPLEMENTATION

Successful implementation and operation of the Water Quality Plan as with other initiatives underway in the estuary (e.g. Environmental Review Committee and Waste Management Activity Plan) depend on continuation of FREMP and its infrastructure. The Management Committee Executive provides senior coordination support and decision making for matters relating to funding, personnel and the establishment of Working Agreements. Actions and commitments in each of these areas will be necessary in implementing the present Water Quality Plan.

Coordination of water quality planning for FREMP is the responsibility of the Water Quality Standing Committee and current agency representation appears appropriate. It is recommended that increased responsibility and decision making be given to the Committee (or the Plan Coordinator through the Standing Committee) by the Executive to facilitate day-to-day operation of the Plan as monitoring and other aspects of the Plan become operational. Matters of policy and jurisdiction should continue to be referred to the Executive for resolution if conflicts arise.

A dramatic increase in workload for the Standing Committee is envisioned after the Plan is implemented. Currently members' agency-related responsibilities preclude further FREMP involvement.

The breakdown of duties for the Standing Committee and the proposed Plan Coordinator is shown in Table 13. Management activities of the Plan are the responsibility of the Standing Committee. These include budgeting, approval of revisions to the Plan, identification of research needs, approval of annual work plans, approval of contract requirements, establishment of agreed-upon Water Quality Objectives and review and approval of reports submitted by contractors and the Plan Coordinator.

Day-to-day administration of aspects of the Plan (e.g. monitoring and logistics) should be the responsibility of the Plan Coordinator. This administration will include ensuring recommended monitoring is being conducted as necessary, supervising contracts for monitoring, coordinating data management and preparation of reports, organizing workshops and acting as the point of contact for public inquiries (Table 13). The Plan coordinator will be supported by a QA/QC officer with responsibility for all aspects of field analytical and data handling, including use of field blanks, verification of field methods and field protocols. Secretarial/ clerical support will be required by the Plan Coordinator and is costed in Table 14.

Cost estimates for implementation of the Plan for each three-year cycle are shown in Table 14. Plan Coordinator, QA/QC Officer and Secretarial salaries amount to $535,000. Ambient monitoring costs including QA/QC for a minimum required program (analytical and reporting) are estimated at $2,200,000 including an allotment of $331,000 for field staff to conduct the field monitoring program. A budget of $300,000 is proposed for research, monitoring and bioassays associated with Water Quality Objective setting. This allotment will allow the Standing Committee to better fulfil its role in establishing agreed-upon Objectives. Included is $600,000 for Required Special Studies and $60,000 for Public Information. The total estimated cost for the Plan is $3,695,000 for the first three-year cycle.

Serious consideration of funding Plan implementation through a special joint arrangement, rather than within existing agency programs, is necessary. Such an approach has successfully been taken in the recent Halifax Harbour research and monitoring initiatives.

Once the Plan is approved and the funding and responsibilities established the Standing Committee will begin the detailed arrangements for implementation.

Table 1. An overview of legislation applicable to water quality management in the Fraser River Estuary. (Details in Appendix I of the Plan).

TOPIC	RELEVANT PRINCIPAL LEGISLATION[1]
Joint basin agreements (e.g. FREMP)	*Canada Water Act*
Environmental impact assessment (Fraser River Estuary)	*Environment and Land Use Act* (B.C.)
Formulation of water quality objectives	*Ministry of Environment Act* (B.C.) *Boundary Waters Treaty* *Canadian Environmental Protection Act*
Regulation of waste discharges	*Waste Management Act* (B.C.) *Fisheries Act* *Health Act* (B.C.)
Review of potentially dangerous substances	*Canadian Environmental Protection Act*
Protection of fish and fish habitat	*Fisheries Act*
Protection of water quality	*Water Act* (B.C.) *Municipal Act* (B.C.) *Fisheries Act* *Canadian Environmental Protection Act* *Waste Management Act* (B.C.)
Pesticide control	*Pest Control Products Act* *Pesticide Control Act* (B.C.)
Dumping of dredge or fill	*Navigable Waters Protection Act* *Canadian Environmental Protection Act*
Oil pollution, discharges from ships	*Canada Shipping Act*
Response to environmental emergencies	*Environmental Management Act* (B.C.) *Fisheries Act* *Canadian Environmental Protection Act* *Waste Management Act* (B.C.)
Handling of dangerous goods	*Transportation of Dangerous Goods Act* *Waste Management Act* (B.C.) *Special Waste Regulations* (B.C.)
Fishery product quality	*Fish Inspection Act*
Control of toxic chemicals	*Canadian Environmental Protection Act*
Collection and treatment of sewage and drainage	*Greater Vancouver Sewerage and Drainage District Act* (B.C.)

[1] Legislation not identified as B.C. is federal.

Table 2. Summary of waste discharges by type in each of the three Fraser River reaches and adjacent land areas[1].

Discharge Type	*Main Stem*	*Main Arm*	*North Arm*
Discharges authorized by Waste Management Permit			
Solid waste (on adjacent land base)	10	11	7
Effluent	17	29	24
Combined sewer overflows (without permits)	9	0	14
Stormwater discharges (without permits)	80	43	52
Antisapstain chemical users (under Provincial regulation)	9	4	14

[1] It should be noted that Fraser River flows at Hope vary from 7000 m^3/s at freshet (late spring/early summer), to minimum flows of 800-1000 m^3/s in January to mid-April. Eighty-five percent of the Fraser River's flow is estimated to enter the Main Arm and 15% enters the North Arm.

Table 3. Summary of principal estuary uses and user groups.

User Group	*Designated Uses*	*Major Concerns*
People	• discharge of effluents • recreation • irrigation • fishing (consumption of fish products) • livestock watering • shipping • aquaculture	• potential contact with pathogenic organisms or chemical contaminants • ingestion of fish products with unforseen contamination • aesthetics • water quality to protect fish, wildlife and habitats
Aquatic Life (Fish/Invertebrates)	• migration • spawning • incubation • rearing	• acute or chronic toxic impacts • disruption, degradation or elimination of habitat • biouptake • exposure to chemical and oil spills; high silt loads
Wildlife (Wetland Birds, Marine Mammals, etc.)	• feeding • nesting	• toxicity and bioaccumulation of effluents and contaminants • disruption, degradation and elimination of habitat and food production areas • exposure to chemical and oil spills

Table 4. Summary of recommended monitoring program activities for the three-year cycle.

	Effluents	*Water*	*Sediment*	*Fish*	*Invertebrates*
Year 1 *Sites*	Sewage treatment plants Major industrial Minor industrial	Upstream Reference Main River[1] Slough			
Activities	Sampling, analyses and data interpretation	Sampling, analyses, and data interpretation			
Year 2 *Sites*		Upstream Reference Main River[1] Slough	Upstream Reference Main River[1] Slough Tributary[2] Marine[3]		Slough Marine[3]
Activities		Sampling, analyses, and data interpretation	Sampling, analyses and data interpretation Sediment bioassays		Sampling
Year 3 *Sites*		Upstream Reference Main River[1] Slough		Upstream Reference Main River[1] Slough Marine[3]	
Activities		Sampling, analyses, and data interpretation		Sampling, analyses and data interpretation	Analyses and data interpretation

[1] Main River = Main Stem, North Arm and Main Arm

[2] Tributary = Campbell River, Nicomekl River, Serpentine River and Brunette River

[3] Marine = Boundary Bay, Roberts Bank and Sturgeon Bank

Table 5. Summary of field monitoring sites, compartments and replicates for the recommended monitoring program.

	Upstream Reference	*Main River*	*Selected Tributaries*	*Selected Sloughs*	*Sturgeon and Roberts Banks*	*Boundary Bay*	*Field QA/QC*
WATER							
Chemistry (Year 1,2,3)	1D,1S 26 x per year	1D,2S 26 x per year 1D,2S,4 additional points in the river 4 x per year		2D,6S 2 X per year			$\sqrt{n}=\sqrt{134}$ ≈ 12 + 4 add'l samples for QA/QC = [2 standard reference materials + 4 blanks + (5 replicates x 2)]
SEDIMENT							
Chemistry (Year 2)	1S,5R	6S,5R	4S,5R	4S,5R	5S,5R	2S,5R	$\sqrt{n}=\sqrt{110}$ = 11 samples for QA/QC = (6 standard references + 5 split samples)
Bioassay (Year 2)	1S	6S	4S	4S	5S	2S	
BIOTA							
Invertebrates (Year 2)							
Mysids, Amphipods				6S,5R or 5SP			
Crabs					4S,5R,2T	2S,5R,2T	$\sqrt{n}=\sqrt{60}$ = 8 samples for QA/QC = (2 standard reference materials + 6 split samples)
Clams						2S,5R	
Fish (Year 3)							
Resident	1S,5R,2T,2SP	3S,5R,2T,2SP		4S,5R,2T,2SP	2S,5R,2T,2SP	2S,5R,2T,2SP	$\sqrt{n}=\sqrt{240}$ = 16 samples for QA/QC = (5 standard reference materials + 11 split samples
Migratory		1S,5R,2T,2SP					
Histopathology					1S,20R	1S,20R	

D = Depth, S = Site, R = Replicate, SP = Species, T = Tissue Types

$\sqrt{n}=$ square root of number of samples taken (to develop number of QA/QC samples required

Table 6. Recommended effluent discharge monitoring.

CATEGORY 1 *Major municipal sewage treatment plants*[1]

All of the following are to be monitored in the first year of each 3-year cycle.

Lulu Island STP (PE-233)
Annacis Island STP (PE-387)

CATEGORY 2 *Heavy industry (e.g. pulp and paper, chemical plants)*[1]

Half of the following companies will be monitored in the first year of each 3-year cycle.

Paperboard Industries Corporation (PE-17)
Scott Paper (PE-335)
Chatterton Petrochemical (PE-41)
Wolverine Tube (PE-7857)
Titan Steel and Wire (PE-161)
Crown Forest Industries - Fraser Mills (PE-412)
MacMillan Bloedel - New Westminster (PE-1664)
MacMillan Bloedel - Canadian White Pine (PE-1666)
Western Canada Steel (PE-2087)
British Columbia Forest Products - Hammond (PE-2756)
Tree Island Steel (PE-3190)
Domtar (PE-3410)
Hillinex (PE-4962)

CATEGORY 3 *Other*[1]

Two or three of the following will be monitored the first year of each 3-year cycle.

Domtar (PE-3735)
B.C. Packers (PE-1830)
Genstar (PE-4513)
Fraser Surrey Docks (PE-6452)
Westshore Terminals (PE-6819)

---

[1] Waste Management Branch effluent permit numbers included in brackets.

Table 7. Recommended FREMP upstream reference site - water quality monitoring program.

Site Location

- near the Environment Canada gauging station at Mission.

Sampling Methods

- same as those now used at the Federal/Provincial monitoring site at Hope.
- samples collected 1 m below the surface.

Sampling Frequency

- 26 times per year (bi-weekly).
- low flow (pre-freshet).
- autumn first flush (September - November).
- sampling to be conducted on the outgoing tide before low slack in a tidal cycle of moderate range.

Sampling Parameters

- temperature, pH, total alkalinity, hardness, dissolved and total metals (ICAP scan), selected ions and nutrients, non-filterable residue, filterable residue, ammonia, fecal coliform and total organic carbon.

Additional Characteristics

- chlorophenols and other wood protection/preservation chemicals.
- resin acids.
- guaiacols, catechols, selected pesticides, nonylphenol.
- sampling frequencies to be determined in a special study.

TABLE 8. List of biota proposed for monitoring - (five samples of a single fish or invertebrate species).

	Roberts Bank Sturgeon Bank Boundary Bay	*Fraser River*	*Tributaries*
Fish			
Resident	Threespine Stickleback	Threespine Stickleback or Prickly Sculpin	Threespine Stickleback or Prickly Sculpin
	Staghorn Sculpin or Starry Flounder or Sole	Peamouth Chub or Largescale Sucker or Northern Squawfish	Peamouth Chub or Largescale Sucker or Northern Squawfish or Starry Flounder
Migratory	Salmonid[1]	Salmonid[1]	Salmonid[1]
	Eulachon	Eulachon	Carp
Invertebrates	Crabs		
	Bivalves (Clams or Mussels)		
	Mysids and Amphipods	Mysids and Amphipods	

[1] chinook fry recommended

Table 9. Summary of field personnel requirements (days)[1].

	Year 1	*Year 2*	*Year 3*
Effluent	190	-	-
Water	100	80	80
Sediment	-	72	-
Fish	-	-	144
Invertebrates	-	72	-

[1] sample collection and preparation for analysis

Table 10. Monitoring program analytical cost estimates ($000's)[1].

	Year 1	*Year 2*	*Year 3*	*3-Year Costs*
EFFLUENT				80
All Areas	80	-	-	
WATER				411
Upstream Reference	23	25	28	
Main River	74	80	88	
Selected Sloughs	15	17	19	
QA/QC	12	14	16	
SEDIMENT				257
Upstream Reference	-	12	-	
Main River	-	64	-	
Tributaries	-	42	-	
Selected Sloughs	-	42	-	
Sturgeon/Roberts Banks	-	52	-	
Boundary Bay	-	23	-	
QA/QC		23		
SEDIMENT BIOASSAY				15
All Areas	-	15	-	
RESIDENT FISH				396
Upstream Reference	-	-	30	
Main River	-	-	93	
Selected Sloughs	-	-	124	
Sturgeon/Roberts Banks	-	-	62	
Boundary Bay	-	-	62	
QA/QC			25	
MIGRATORY FISH				30
Main River	-	-	30	
FISH HISTOPATHOLOGY				18
Selected Sloughs	-	-	10	
Sturgeon/Roberts Banks	-	-	5	
Boundary Bay	-	-	3	
CRABS				90
Sturgeon/Roberts Banks	-	-	50	
Boundary Bay	-	-	25	
QA/QC			15	
OTHER INVERTEBRATES				57
Selected Sloughs	-	57	-	
TOTAL ANALYTICAL COSTS	204	465	685	1354

---

[1] 10% inflationary costs have been added per annum

Table 11. Monitoring program total cost estimates[1] ($000's)[2].

	Year 1	*Year 2*	*Year 3*	*3-Year Costs*
Analytical Costs	204	465	685	1,354
Field Collection Costs	100	110	121	331
Nonroutine Quality Assurance/ Quality Control @ 15% of Analytical and Field Costs[3]	45	85	120	250
Data Analysis and Interpretation	30	15	20	65
Reporting	10	25	30	65
Capital Costs	50	25	60	135
TOTALS	439	730	1036	2,200

[1] Costs are estimates only, funding has not yet been approved.
[2] 10% inflationary costs have been added per annum.
[3] Routine QA/QC is included in Table 5.

Table 12. Suggested Special Studies.

Description	*Agency*
Investigations of the significance of selected contaminants in fish with respect to the health and survival of key species.	DFO Universities
Investigations of the feasibility of using various sensitive laboratory and *in situ* toxicological testing techniques (bio-monitoring techniques) as screening tools for assessing water quality conditions in dilution zones and ambient waters of the Fraser River.	DOE MOE DFO Consultants
Studies on impacts of exposure of fish to selected contaminants and/or effluents under hypoxic conditions to facilitate research on combined effects of low DO and pollutants.	DFO Consultants
Studies on the quality of stormwater inputs from residential, industrial and agricultural catchment areas.	DOE, MOE GVRD
Studies to characterize combined sewer overflows from different catchments.	GVRD, MOE
Investigations of the types and amounts of agricultural pesticides being used in the Lower Mainland and potential for their release into the Fraser River and its tributaries	DOE MOE
Studies on PAH levels in biota and sediments near creosote-treated wharves and pilings, and in the vicinity of wood preservation facilities using creosote.	DOE
Measurements of organotin (antifoulant) and sediment metals near marinas in the Fraser River Estuary. Highly toxic organotins (tributyltin) have been widely used as antifouling agents in marine paints.	DOE
Histopathological studies of selected resident fish (e.g. flatfish) from areas receiving effluents for comparison with upstream, less contaminated areas of the estuary.	DOE
A survey of representative sites throughout the FREMP study area for toxics in precipitation. Locations could be selected for ease of long term automated sampling. Such information would provide data on the importance of atmospheric sources of contaminants in the study area.	MOE GVRD DOE AES
A study on the sources of mercury in the lower Fraser.	DOE, MOE
Monitoring of stormwater from Mitchell and Annacis Islands to better characterize contamination from this highly industrialized area.	DOE GVRD
A study to determine the levels of fecal coliforms in the Main and North Arms in winter when the sewage treatment plants are not disinfecting effluents. This study is advisable to determine potential risks to users of the estuary during the winter.	Health GVRD DOE, MOE
Investigations on life history, feeding habits and movements of common resident fish species used for contaminant monitoring (i.e. starry flounder) to enable sound interpretation of contaminants data in fish.	DFO Universities
Video taping of key estuarine areas to include FREMP study sites and known effluent outfalls. This program should be combined with area designation activities under the FREMP Habitat Management Activity Program.	DFO MOE
Analysis of contaminants in eulachons. Study would determine degree to which eulachons should be used as integrators of organic contaminants during migration through the Fraser River Estuary.	DFO
In conjunction with other studies proposed by DFO in coastal and interior systems on bioavailability of metals under acid/non acid conditions and the biological significance of metal state (dissolved vs. total vs. complexed), a study should be implemented to examine metals bioavailability in Lower Fraser River water and to relate the results to seasonal suspended sediment regimes, metals speciation and water quality objectives for fish.	DFO DOE

Table 13. Proposed duties of the Standing Committee and Plan Coordinator.

Standing Committee	*Plan Coordinator*
Directs activities of coordinator.	Manages implementation of monitoring program in consultation with Standing Committee.
Reviews and develops Water Quality Objectives.	Coordinates data management and preparation of summary reports.
Plans reviews and appropriate revisions of the Water Quality Plan.	Conducts annual survey and Workshop on Monitoring and Research and prepares associated reports.
Identifies and promotes appropriate research for implementation.	Acts as a point of contact for public inquiries on the Plan.
Reviews and approves Fraser River Status Reports.	Maintains contact and information exchange with FREMP Activity Programs.
Reviews reports submitted by coordinator prior to publication.	Supervises any contracts for monitoring or report preparation.
Prepares annual budget and expenditure estimates.	Supervises QA/QC officer.
	Prepares Fraser River Status Reports.

Table 14. Water Quality Plan costs estimated for three-year cycle ($000's).

Component	*Priority I (Funded through FREMP)*
Plan Coordinator	225
QA/QC Officer	190
Secretarial/Data Services	120
Routine Monitoring Program	2,200
Water Quality Objectives Development	300
Required Special Studies	600
Public Information	60
Total	*3,695*

	Priority II (High priority for agency programs)
University Chair (Aquatic Environmental Toxicology)	
Suggested Special Studies	

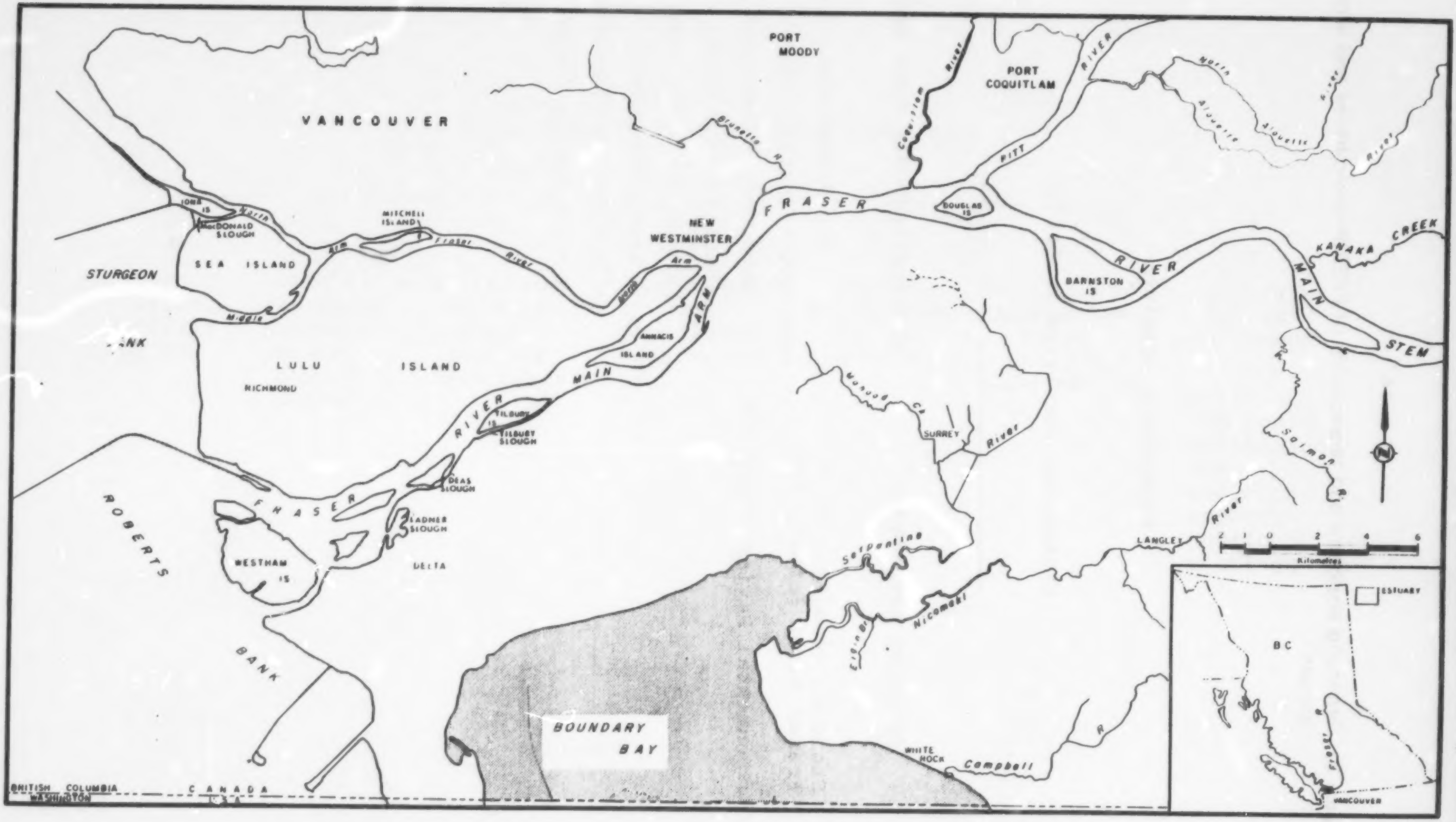

PORT MOODY
PORT COQUITLAM
VANCOUVER
Coquitlam River
PITT RIVER
North Alouette River
Alouette
Brunette R
IONA IS
McDONALD SLOUGH
North Arm Fraser River
MITCHELL ISLAND
NEW WESTMINSTER
FRASER RIVER MAIN STEM
DOUGLAS IS
KANAKA CREEK
BARNSTON IS
STURGEON BANK
SEA ISLAND
Middle Arm
ANNACIS ISLAND
ARM
LULU ISLAND
RICHMOND
MAIN
Bonson Cr
SURREY
River
TILBURY IS
TILBURY SLOUGH
Salmon R
DEAS SLOUGH
LADNER SLOUGH
FRASER
ROBERTS
WESTHAM IS
DELTA
Serpentine
Nicomekl
Elgin Br
LANGLEY
River
BANK
BOUNDARY BAY
WHITE ROCK
Campbell
R
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.
2 1 0 2 4 6
Kilometres
N
ESTUARY
BC
Fraser R
VANCOUVER

FIGURE I The Fraser River Estuary Management Program Study Area (Fraser River Main Stem downstream of Kanaka Creek confluence; Pitt River downstream of Pitt Lake; Sturgeon and Roberts Banks and Boundary Bay)

Figure 2. Reporting structure and relationship of FREMP committees and work groups.

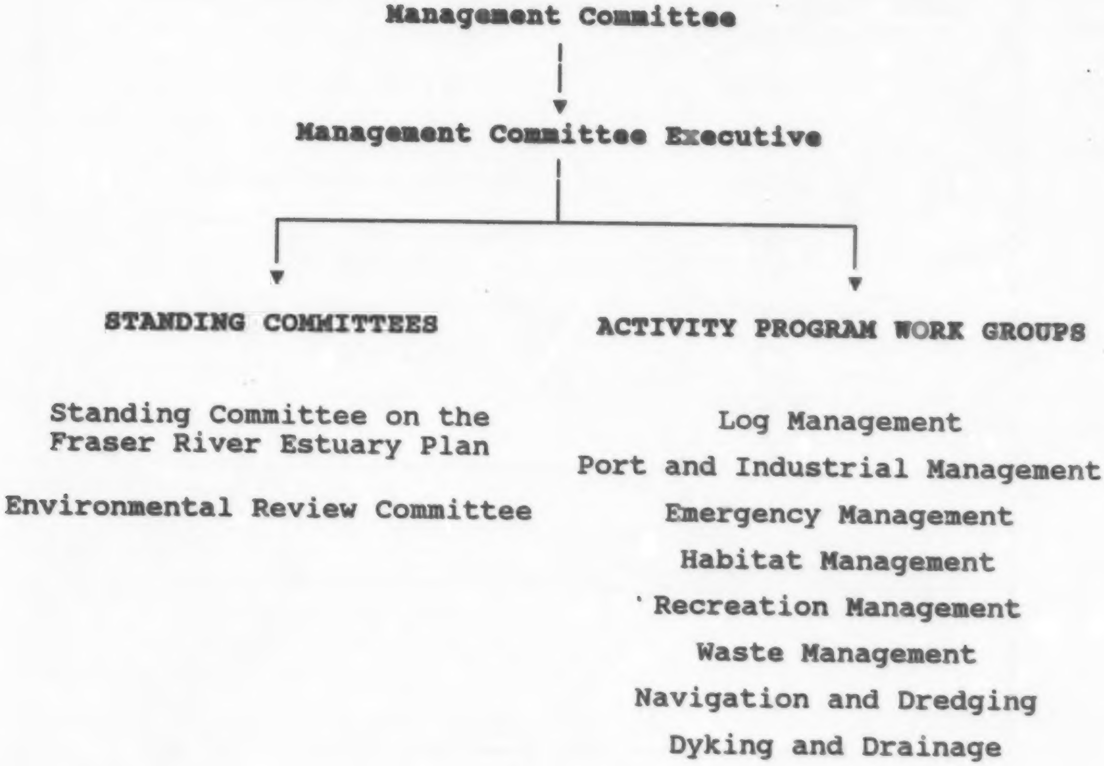

Management Committee
Management Committee Executive
STANDING COMMITTEES
ACTIVITY PROGRAM WORK GROUPS
Standing Committee on the Fraser River Estuary Plan
Environmental Review Committee
Log Management
Port and Industrial Management
Emergency Management
Habitat Management
Recreation Management
Waste Management
Navigation and Dredging
Dyking and Drainage

Figure 3. Roles of the Water Quality Plan Standing Committee.

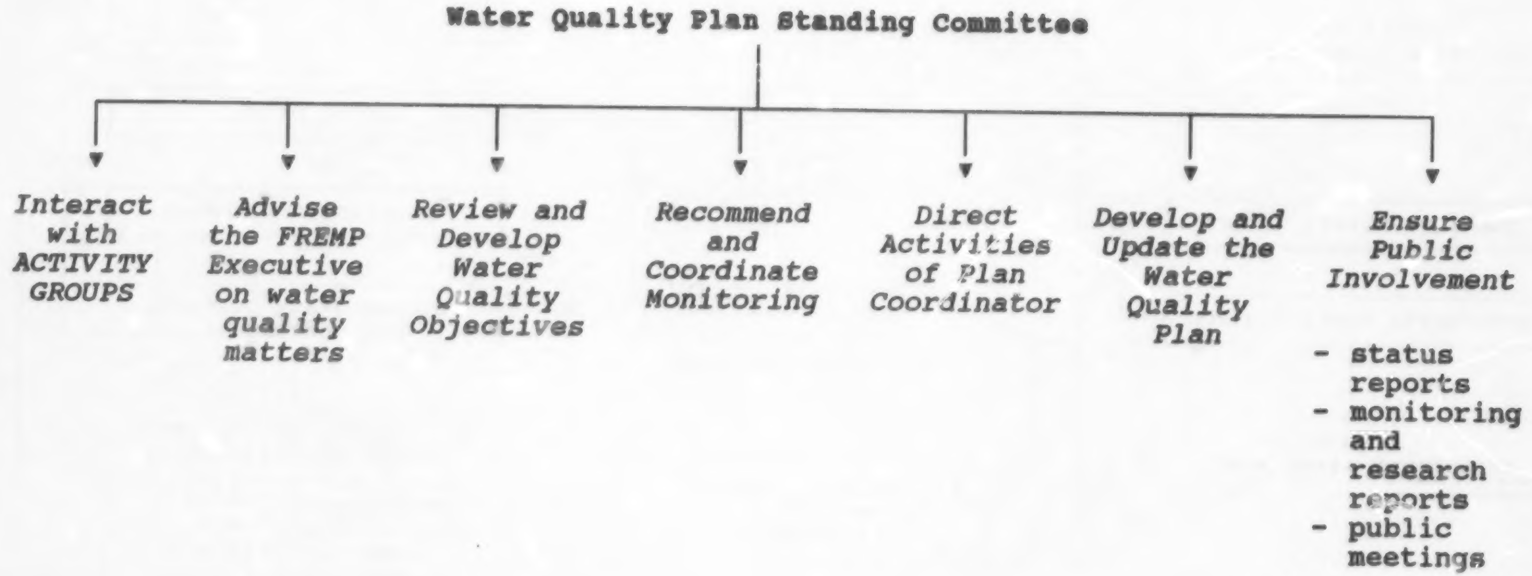
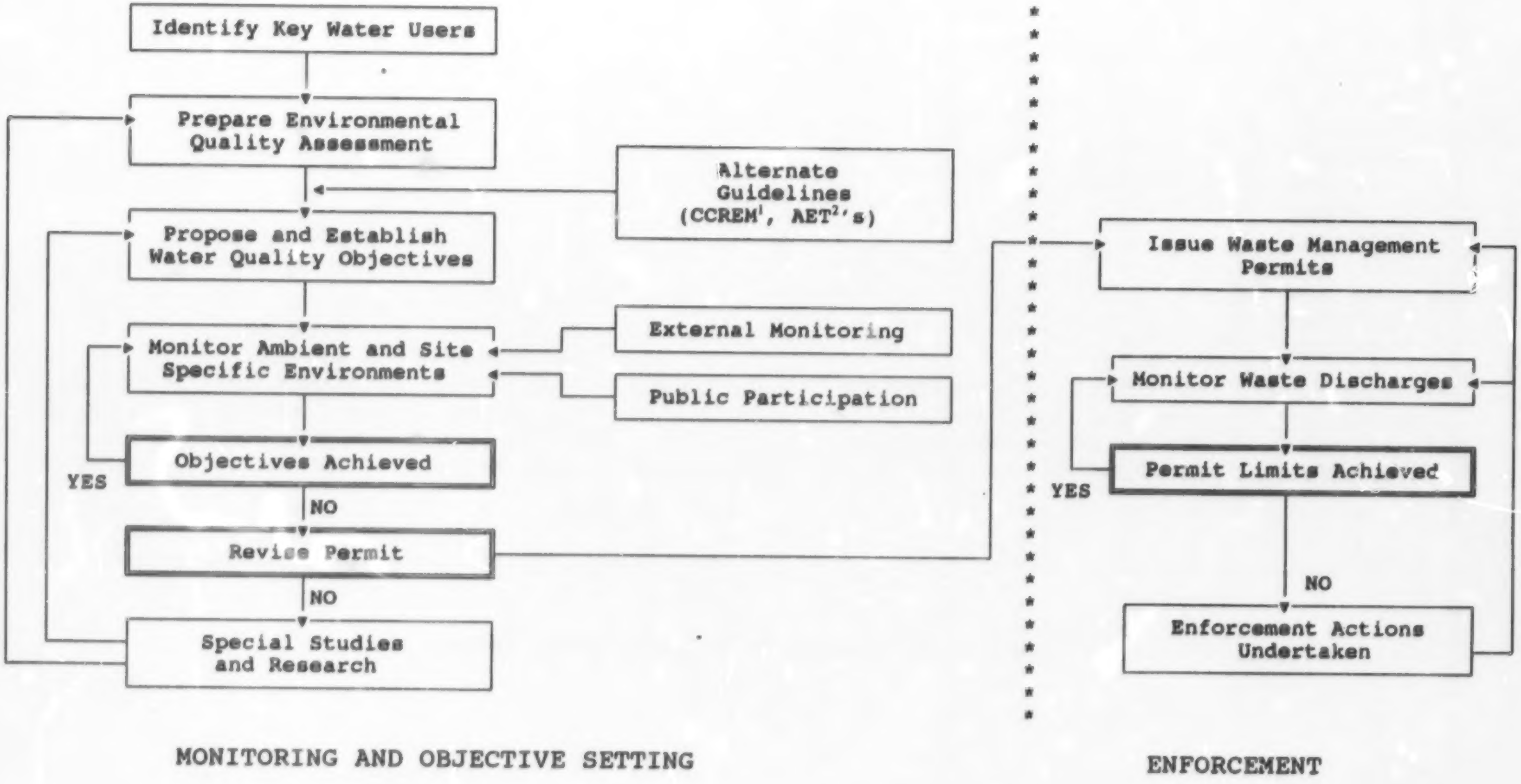

Water Quality Plan Standing Committee
Interact with ACTIVITY GROUPS
Advise the FREMP Executive on water quality matters
Review and Develop Water Quality Objectives
Recommend and Coordinate Monitoring
Direct Activities of Plan Coordinator
Develop and Update the Water Quality Plan
Ensure Public Involvement
- status reports
- monitoring and research reports
- public meetings

Figure 4. Key components in updating the Water Quality Plan.


Identify Key Water Users
Prepare Environmental Quality Assessment
Alternate Guidelines (CCREM¹, AET²'s)
Propose and Establish Water Quality Objectives
External Monitoring
Public Participation
Monitor Ambient and Site Specific Environments
Objectives Achieved
YES
NO
Revise Permit
NO
Special Studies and Research
Issue Waste Management Permits
Monitor Waste Discharges
Permit Limits Achieved
YES
NO
Enforcement Actions Undertaken
MONITORING AND OBJECTIVE SETTING
ENFORCEMENT

1 - Canadian Council of Resource and Environmental Ministers
2 - Apparent Effects Threshold

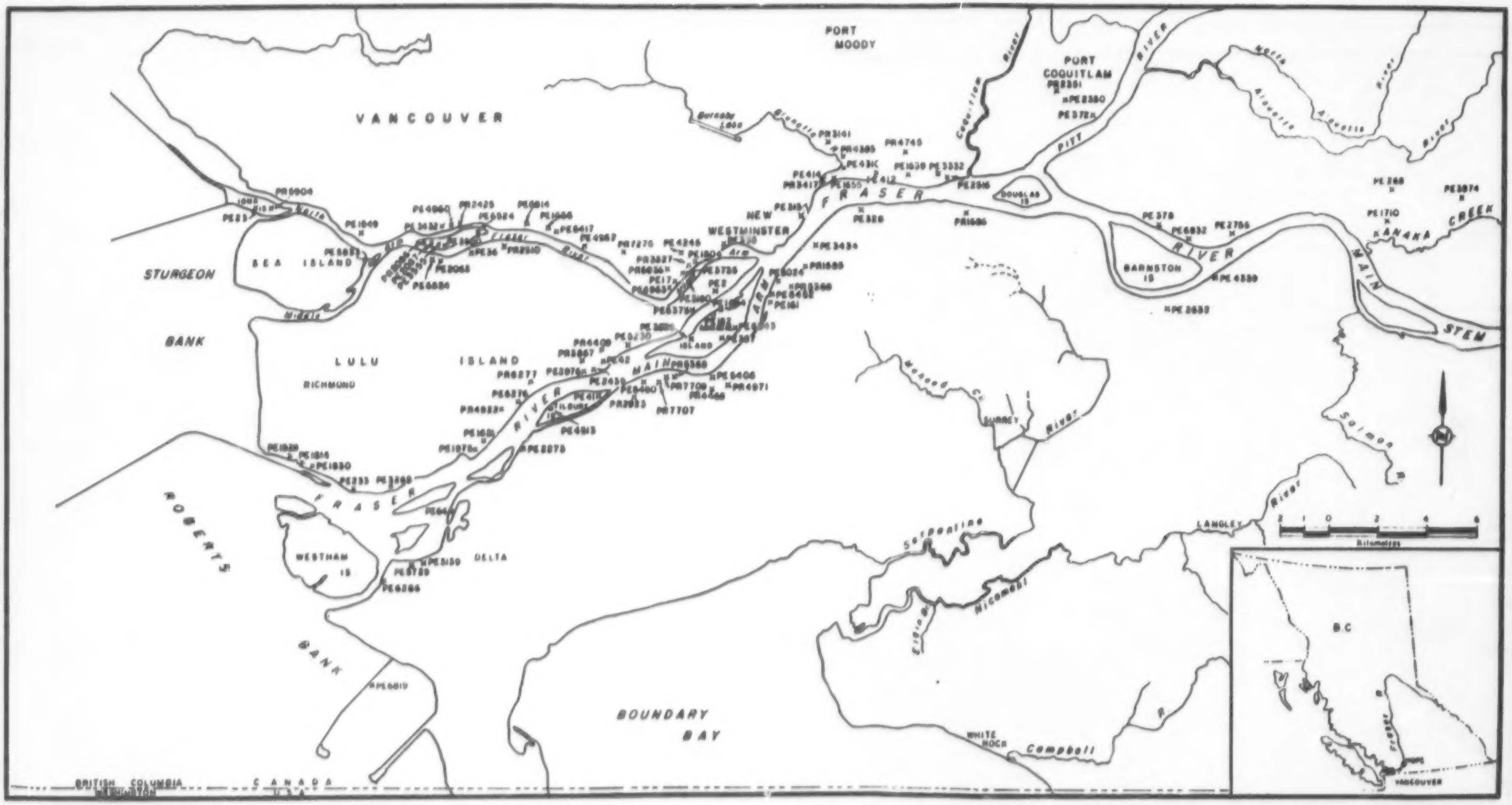

VANCOUVER
PORT MOODY
PORT COQUITLAM
PR2381
PE2380
PE372
Coquitlam River
PITT RIVER
Alouette River
North Alouette River
PE268
PE3874
PE1710
KANAKA CREEK
MAIN STEM
FRASER RIVER
DOUGLAS IS
BARNSTON IS
PE378
PE6832
PE2756
PE4330
PE2632
PR4745
PR3141
PR4385
PE431C
PE1630
PE3332
PE414
PR3417
PE1655
PE412
PE2316
PE326
PR1686
NEW WESTMINSTER
PE319
PE3434
PR1685
PE5024
PE161
ANN
Arm
Burnaby 1000
Brunette
PR5904
PE23
PE1049
PE4060
PR2425
PE6024
PE6914
PE1666
PE6417
PE4967
PR7276
PE4246
PR3827
PR6036
PE17
PE3735
PE2
PE6378
PE36
PR2510
PE5063
PE6684
Fraser River
Middle
SEA ISLAND
STURGEON BANK
LULU ISLAND
RICHMOND
PR4408
PE3230
PR3857
PE42
PR6277
PE2076
PE2435
MAIN
PE6408
PR4971
PR7709
PR7707
PR2833
PE6276
PR4832
PE4813
PE1621
PE1075
PE2273
PE1829
PE1616
PE1830
PE233
PE2260
FRASER
WESTHAM IS
DELTA
PE3130
PE5729
PE6266
ROBERTS BANK
PE6819
BOUNDARY BAY
Serpentine
Nicomekl
Surrey River
Salmon R.
LANGLEY
WHITE ROCK
Campbell
Kilometres
2
1
0
2
4
6
B.C
VANCOUVER
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.

FIGURE 5 Discharges into the Lower Fraser River under Provincial Permit

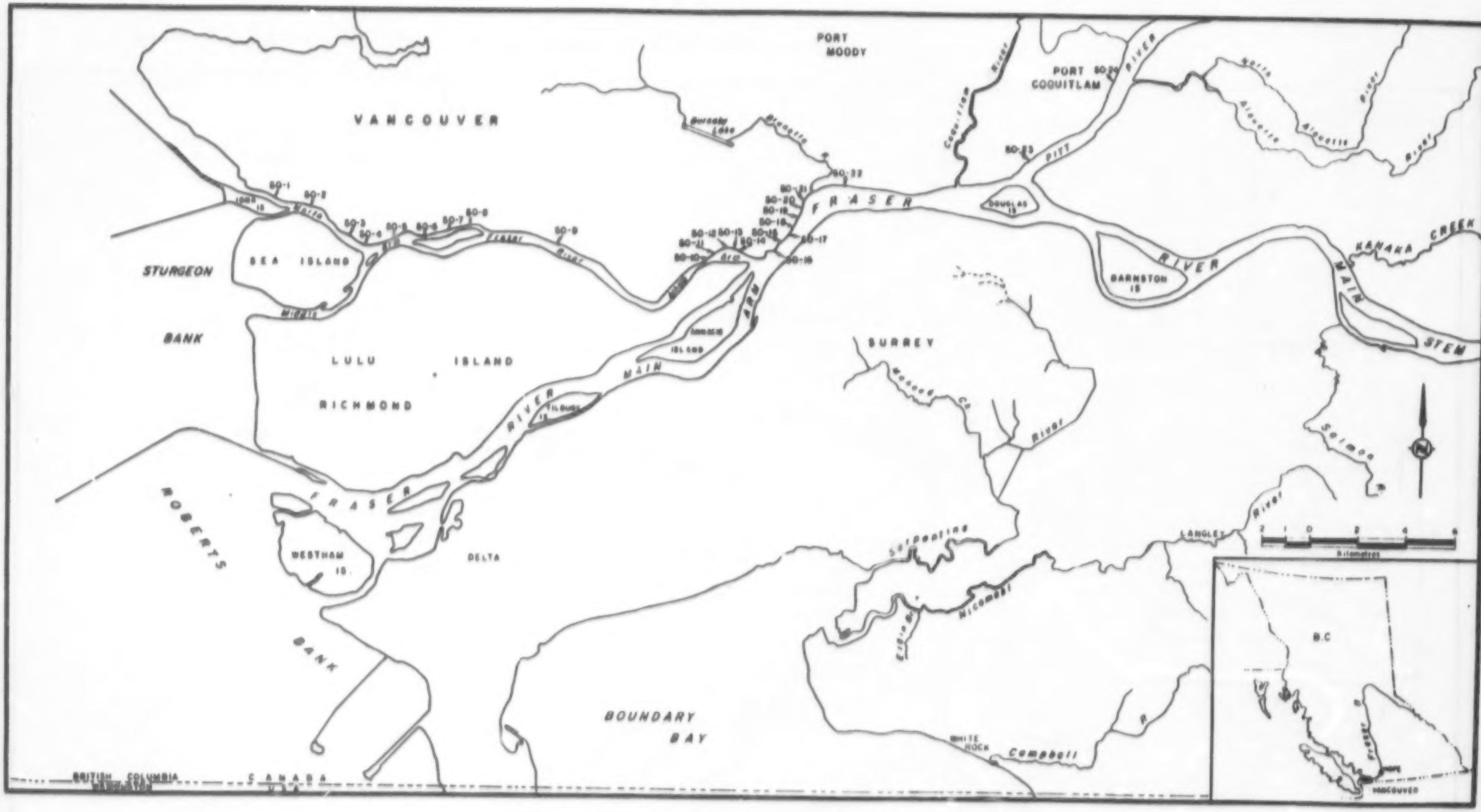

VANCOUVER
PORT MOODY
PORT COQUITLAM
Burnaby Lake
Brunette R.
Coquitlam River
PITT RIVER
North Alouette
Alouette River
SO-1
SO-2
SO-3
SO-4
SO-5
SO-6
SO-7
SO-8
SO-9
SO-10
SO-11
SO-12
SO-13
SO-14
SO-15
SO-16
SO-17
SO-18
SO-19
SO-20
SO-21
SO-22
SO-23
SO-24
IONA IS.
North Arm
Fraser River
Middle Arm
STURGEON
BANK
SEA ISLAND
LULU ISLAND
RICHMOND
ANNACIS ISLAND
TILBURY IS.
MAIN ARM
FRASER RIVER
MAIN STEM
DOUGLAS IS.
BARNSTON IS.
KANAKA CREEK
SURREY
Bear Cr.
River
Salmon R.
Nicomekl
Serpentine
LANGLEY
Little Campbell
Campbell
WHITE ROCK
ROBERTS
BANK
WESTHAM IS.
DELTA
BOUNDARY BAY
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.
2 1 0 2 4 6
Kilometres
B.C.
Fraser R.
VANCOUVER
HOPE

FIGURE 6 Combined Sewer Overflows Into the Lower Fraser River

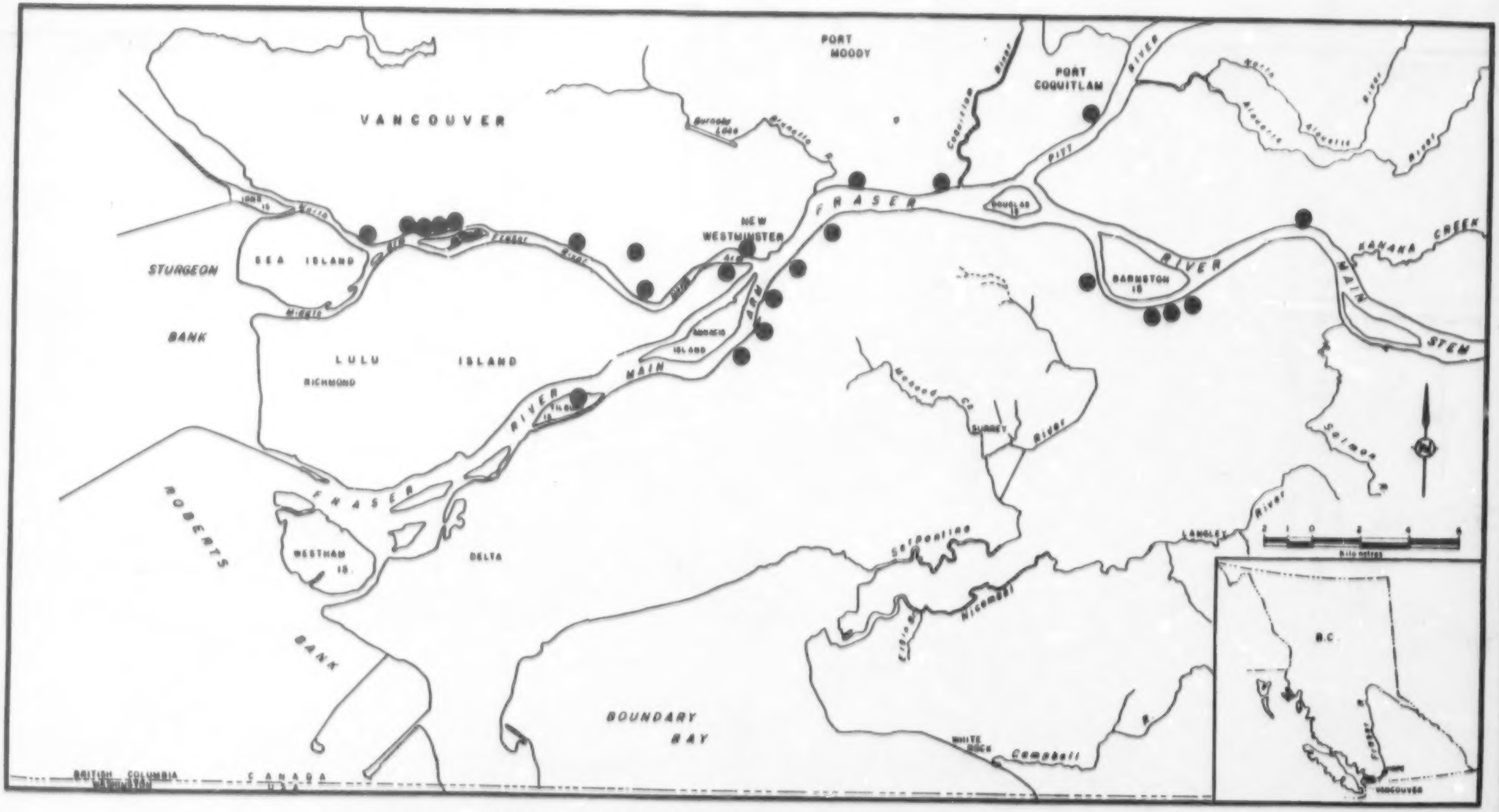

VANCOUVER
PORT MOODY
PORT COQUITLAM
NEW WESTMINSTER
STURGEON BANK
SEA ISLAND
LULU ISLAND
RICHMOND
ROBERTS BANK
WESTHAM IS.
DELTA
BOUNDARY BAY
WHITE ROCK
FRASER RIVER
MAIN ARM
MAIN STEM
BARNSTON IS
DOUGLAS IS
ANNACIS ISLAND
SURREY
LANGLEY
Pitt River
Coquitlam River
Kanaka Creek
Salmon R.
Serpentine
Nicomekl
Campbell
Alouette
Kilometres
B.C.
VANCOUVER
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.

FIGURE 7 Sites of Antisapstain Chemical Usage in the Lower Fraser River

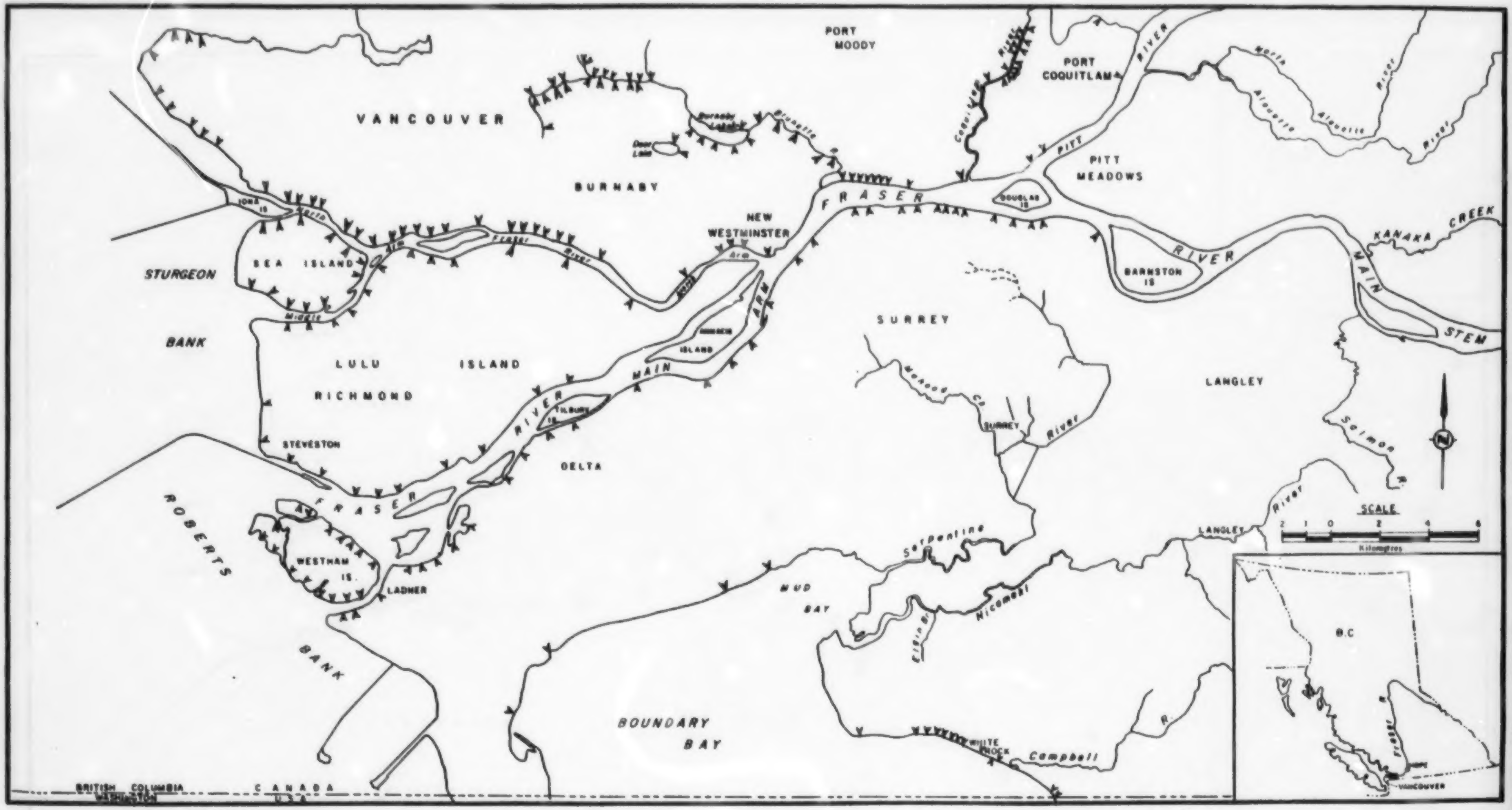
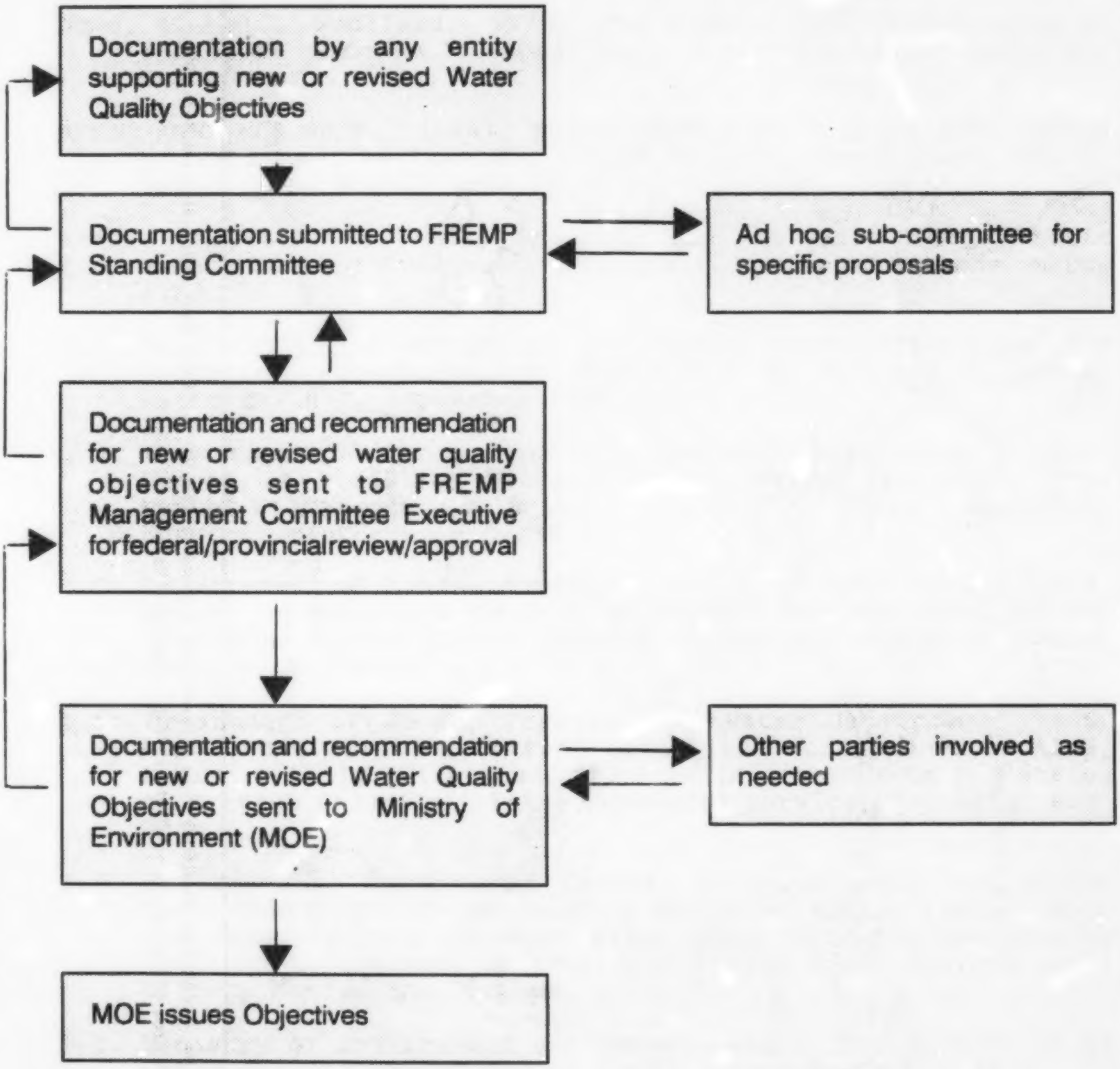

PORT MOODY
PORT COQUITLAM
VANCOUVER
BURNABY
Burnaby Lake
Deer Lake
Brunette R.
Coquitlam River
PITT RIVER
PITT MEADOWS
North Alouette River
Alouette
DOUGLAS IS
NEW WESTMINSTER
FRASER
Fraser River
North Arm
Middle Arm
IONA IS
STURGEON BANK
SEA ISLAND
LULU ISLAND
RICHMOND
STEVESTON
ANNACIS ISLAND
MAIN ARM
RIVER
TILBURY IS
MAIN
DELTA
FRASER
WESTHAM IS.
LADNER
ROBERTS BANK
BARNSTON IS
RIVER
KANAKA CREEK
MAIN STEM
SURREY
Bear Cr.
SURREY
River
LANGLEY
Salmon R.
LANGLEY
River
Serpentine
MUD BAY
Nicomekl
Elgin R.
BOUNDARY BAY
WHITE ROCK
Campbell R.
SCALE
2 1 0 2 4 6
Kilometres
B.C
Fraser R.
HOPE
VANCOUVER
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A

FIGURE 8 Point Source Discharges into the Lower Fraser River

FIGURE 9 Mechanism to Develop Agreed-Upon Water Quality Objectives for the FREMP Study Area


Documentation by any entity supporting new or revised Water Quality Objectives
Documentation submitted to FREMP Standing Committee
Ad hoc sub-committee for specific proposals
Documentation and recommendation for new or revised water quality objectives sent to FREMP Management Committee Executive for federal/provincial review/approval
Documentation and recommendation for new or revised Water Quality Objectives sent to Ministry of Environment (MOE)
Other parties involved as needed
MOE issues Objectives

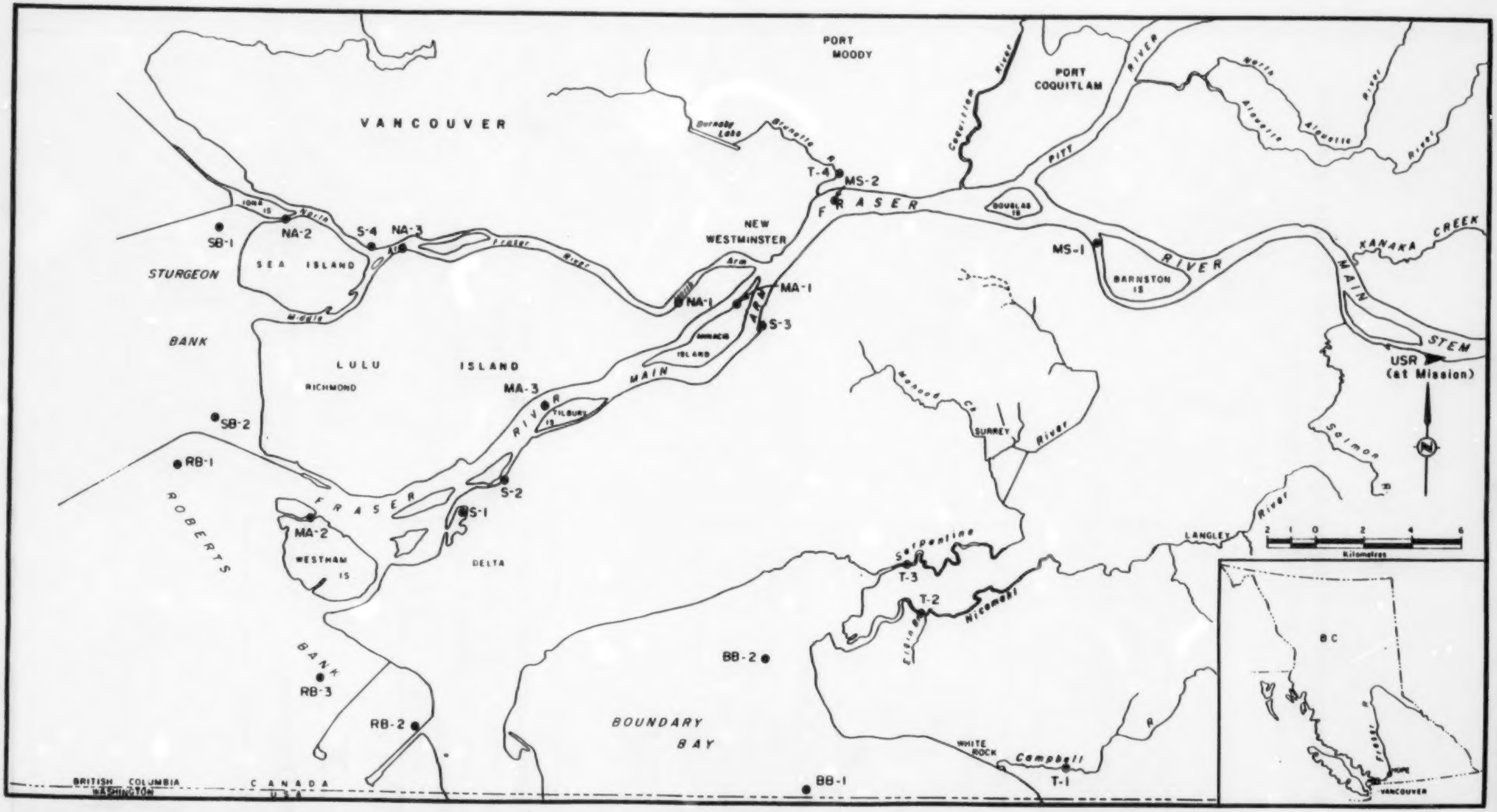

PORT MOODY
PORT COQUITLAM
VANCOUVER
NEW WESTMINSTER
FRASER
RIVER
MAIN STEM
KANAKA CREEK
USR (at Mission)
Pitt River
Coquitlam River
North Alouette
Alouette River
Burnaby Lake
Brunette R.
Douglas IS
Barnston IS
T-4
MS-2
MS-1
Iona IS
North Arm
Fraser River
SB-1
NA-2
S-4
NA-3
SEA ISLAND
STURGEON
BANK
Middle Arm
NA-1
MA-1
S-3
Annacis Island
LULU ISLAND
RICHMOND
MA-3
Tilbury IS
Main Arm
SB-2
RB-1
ROBERTS
BANK
RB-3
RB-2
S-2
S-1
MA-2
WESTHAM IS
DELTA
Surrey
Serpentine
Nicomekl
T-3
T-2
Langley
Salmon R.
BB-2
BB-1
BOUNDARY BAY
White Rock
Campbell
T-1
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.
Kilometres
2 1 0 2 4 6
BC
Fraser R.
HOPE
VANCOUVER

FIGURE 10 FREMP Water Quality Plan Monitoring Sites (Legend: BB – Boundary Bay, RB – Roberts Bank, SB – Sturgeon Bank, MS – Main Stem, MA – Main Arm, NA – North Arm, S – Slough, T – Tributary, URS – Upstream Reference Site)

REFERENCES

Ages, A. 1979. The salinity intrusion in the Fraser River: salinity, temperature and current observations, 1976, 1977. Pacific Marine Science Report 79-14, Institute of Ocean Sciences, Patricia Bay, Sidney, B.C.

Ages, A. and A. Woollard. 1976. The tides in the Fraser estuary. Institute of Ocean Sciences, Pacific Marine Science Report 76-5. 100 p.

APHA, AWWA and WPCF. 1989. Standard Methods for the Examination of Water and Wastewater. 16th Edition, Amer. Publ. Health Assoc., New York, 1193. p.

Arctic Laboratories. 1985. Sampling and Analysis in the Arctic Marine Benthic Environment. Volume 1. Review of Methods. March 1985. 511 p.

B.C. Ministry of Environment and Parks. 1986. Principles For Preparing Water Quality Objectives In British Columbia. Victoria, B.C. September 1986. 20 p.

B.C. Department of Lands, Forests, and Water Resources. 1975. Report on Pollution Control Objectives for Municipal Type Waste DIscharges in British Columbia. Water Resources Service, Victoria, B.C. 35 p.

B.C. Department of Lands, Forests, and Water Resources. 1980. Report on Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia. Water Resources Service, Victoria, B.C. 36 p.

B.C. Department of Lands, Forests, and Water Resources. 1985. Report on Pollution Control Objectives for Food-Processing, Agriculturally Orientated, and Other Miscellaneous Industries of British Columbia. Water Resources Service, Victoria, B.C. 35 p.

B.C. Environment, Environment Canada, Northwood Pulp and Timber Ltd., Canfor Prince George Pulp and Paper Mills, Cariboo Pulp and Paper Company, Quesnel River Pulp, Hatfield Consultants Ltd. 1990. Summary of the Upper Fraser River Environmental Effects Monitoring Program, 1989.

B.C. Ministry of Environment and Parks. 1988. The Attainment of Water Quality Objectives in 1987. Victoria, B.C. 98 p.

B.C. Ministry of Environment. 1989. The Attainment of Ambient Water Quality Objectives in 1988. November 1989. Victoria, B.C. 166 p.

B.C. Ministry of Environment. 1990. The Attainment of Ambient Water Quality Objectives in 1989. Draft Report.

B.C. Pollution Control Board. 1977. Pollution Control Objectives for the Forest Products Industry of British Columbia. B.C. Ministry of the Environment, Victoria, B.C. 18 p.

B.C. Pollution Control Board. 1979. Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia. B.C. Ministry of the Environment, Victoria, B.C. 16 p.

Beamish, R.J. and J.C. VanLoon. 1977. Precipitation loading of acid and heavy metals to a small acid lake near Sudbury, Ontario. J. Fish. Res. Bd. Can. 34: 649-658.

Birtwell, I.K., M.D. Nassichuk and H. Beune. 1987. Underyearling sockeye salmon (*Oncorhynchus nerka*) in the estuary of the Fraser River, p. 25-35. *In*: H.D. Smith, L. Margolis and C.C. Wood [ed.]. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Butler, R.W. 1986. The birds of the Fraser River lowlands: populations, ecology and international significance. Draft, Canadian Wildlife Service, Delta, Occasional Paper. 85 p. plus tables.

Butler, R.W. and R.W. Campbell. 1987. The birds of the Fraser River delta: population ecology and international significance. CWS Occasional Papers No. 65. 73 p.

Cain, R.T. and L.G. Swain. 1980. Fraser River Estuary Study: water quality. Municipal effluents. Fraser River Estuary Study, Ministry of Environment, Victoria. 101 p.

Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines. March 1987.

Churchland, L.M., G. Kan and A. Ages. 1982. Variation in fecal pollution indicators through tidal cycles in the Fraser River estuary. Can. J. Microbiol. 28: 239-247.

Clark, M.J.R. (editor). 1990. Active Protocols of the QA Work Group to the Canada - B.C. Water Quality Monitoring Agreement. May 22, 1990.

Clark, M.J.R. and P.K. Krahn. 1981. Dry Weather Storm Sewer Discharges, Ministry of Environment, Victoria. 102 p.

Clark, M.J.R. (editor), and W.P. Shera (past editor). 1985. Methods of Aquatic Data Collection in British Columbia: A Catalogue. June 1984, Revised June 1985. MOE Manual #7. 353 p.

Department of Environment and Department of Fisheries and Oceans. 1979. Environment Canada, Conservation and Protection, Pacific and Yukon Region Laboratory Manual.

Department of Fisheries and Oceans, Pacific Region. 1989a. The Fraser River of Opportunity. Prepared for Members of Parliament - B.C. Caucus of the Progressive Conservative Party of Canada.

Department of Fisheries and Oceans. 1989b. Unpublished Study by R.U. Kistritz Ltd.

Department of Fisheries and Oceans. 1981. Unpublished Study by EVS Consultants Ltd.

Department of Fisheries and Oceans and Fraser River Harbour Commission. 1990. Environmental Management Plan For the Fraser River Harbour. July 1990. 26 p.

Department of Fisheries and Oceans and North Fraser Harbour Commission. 1989. North Fraser River Harbour Environmental Management Plan. September 1988. 27 p.

Environment Canada. 1980. Susceptibility of aquatic ecosystems to the effects of atmospheric pollutant fallout int he Quebec region. Inland Waters Directorate, Quebec Region. Rep. No. 1253878. 53 p. plus appendices.

Ferguson, K.D. and B.H. Kay. 1978. Shellfish growing water sanitary survey of Semiahmoo Bay and selected areas of Boundary Bay. EPS, Environment Canada, Vancouver, Regional Program Rept. 78-11. 100 p.

Fraser River Estuary Management Program, Log Management Activity Work Group. 1987. Report of the Log Management Activity Work Group, New Westminster, British Columbia.

Fraser River Estuary Management Program Review Committee. 1984. An Implementation Strategy for the Fraser River Estuary Management Program. May 1984. 45 p.

Fraser River Estuary Study - Phase 2. 1982. A Living River By the Door. A Proposed Management Program for the Fraser River Estuary. March 1982. Surrey B.C. 64 p.

Fraser River Estuary Study Recreation Work Group. 1978. Fraser River Estuary Study: recreation. Recreation Work Group, Ministry of Environment, Victoria, 67 p. + appendices.

Fraser River Estuary Study Steering Committee. 1978. Fraser River Estuary Study. Key findings and recommendations Summary proposals for develop. estuary mgmt. plan. Fraser River Estuary Study, Ministry of Environment, Victoria, 22 p.

Goyette, D. and J. Boyd. 1989. Distribution and environmental impact of selected benthic contaminants in Vancouver Harbour, B.C. 1985-1987. Environment Canada, Conservation and Protection, Environmental Protection, Pacific and Yukon Region. Regional Program Report 89-02.

Greater Vancouver Regional District. 1989. Stage 1, Liquid Waste Management Plan. February 1989. Burnaby, B.C. 152 p.

Greater Vancouver Sewerage and Drainage District. 1990. Bacteriological Quality of the Bathing Waters at the Beaches of English Bay, Point Grey, and Iona Island (May 1 to September 30, 1989).

Hall, K.J. 1985. A review of toxic substances in the Fraser River estuary. *In*: Proceedings of the Workshop on Toxic Chemical Research Needs in the Lower Fraser River, June 19, 1985. Environment Canada.

Harvey, C., K. Melliship and N.C. Toner. 1982. Fraser River Estuary Study, Phase II: Results of public involvement program. Environment Canada, Vancouver, B.C. 76 p.

Higgins, P.S., I.K. Birtwell, B.T. Atagi, D. Chilton, M. Gang, G.M. Kruzynski, H. Mahood, G.E. Piercey, B.A. Raymond, I.H. Rogers, and S. Spohn. 1987. Some characteristics of the eulachon (*Thaleichthys pacificus*) captured in the Fraser River Estuary, B.C., April 1986. Can. Manus. Rep. Fish. Aquat. Sci. No. 1913. West Vancouver, B.C. January 1987.

Kennett, K. and M. McPhee. 1988. The Fraser River Estuary: An Overview of Changing Conditions. Fraser River Estuary Management Program. 31 p.

Krahn, P.K., J.A. Shrimpton and R.D. Glue. 1987. Assessment of storm water related chlorophenol releases from wood protection facilities In British Columbia. Environment Canada, Conservation and Protection, Environmental Protection. Regional Program Report 87-14. August 1987. North Vancouver, B.C. 109 p.

Lawson, E.M., G.B. Mitchell and D.G. Walton. 1985. Stormwater monitoring in an industrial catchment basin located in Burnaby, British Columbia. B.C. Ministry of Environment. Surrey, B.C. March 1985. 90 p.

Lawson, E.M., G.B. Mitchell and D.G. Walton. 1983. Fraser River water quality at the Pattullo Bridge. Waste Management, B.C. Ministry of Environment. 157 p.

Levy, D.A. and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39(2): 270-276.

McLean, D.G. and M. Church. 1986. A re-examination of sediment transport observations in the lower Fraser River. Progress Rept. No. 4. University of B.C., Dept. of Geography. 56 p. plus tables and figures.

McQuaker, N.R. 1976. A Laboratory Manual For the Chemical Analysis Of Ambient Air, Emissions, Soil and Vegetation. Department of Environment. February 1976. 249 p.

Milliman, J.D. 1980. Sedimentation in the Fraser River and its estuary, southwestern British Columbia (Canada). Estuar. Coastal Mar. Sci. 10: 609-633.

Mix, M.C. 1986. Cancerous Diseases in Aquatic Animals and their Association with Environmental Pollutants: A Critical Literature Review. Marine Environmental Research 20: 1-141.

Myers, M.S., L.D. Rhodes and B.B. McCain. 1987. Pathologic anatomy and pattern of occurrence of hepatic neoplasms, putative preneoplastic lesions and other idiopathic hepatic conditions in English Sole (*Parophrys velatus*) from Puget Sound, Washington. J. Nat. Cancer Inst. 78: 333-363.

Nordin, R.N. and L.W. Pommen. 1986. Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia). Ministry of Environment and Parks. Victoria, B.C. November, 1986. 83 p.

Northcote, T.G., N.T. Johnston and K. Tsumura. 1976. Benthic, epibenthic and drift fauna of the Lower Fraser River. Westwater Research Centre, UBC, Tech. Rept. 11. 227 p.

Northcote, T.G., N.T. Johnston and K. Tsumura. 1975. Trace metal concentrations in Lower Fraser River fishes. Westwater Research Centre, UBC, Tech. Rept. 7. 41 p.

Oehme, M., A. Bartonova and J. Knutzen. 1990. Estimation of polychlorinated dibenzofuran and dibenzo-ρ-dioxin contamination of a coastal region using profiles in crabs. Environ. Sci. Technol. 24(12): 1836-1841.

PTI Environmental Services. 1990. A project manager's guide to requesting and evaluating chemical analyses (draft). Report to U.S. EPA, Region 10, Office of Puget Sound, Seattle, Washington.

PTI Environmental Sciences. 1987. Policy Implications For Effects-Based Marine Sediment Criteria.

Rocchini, R.J. 1987. Ministry of Environment and Parks. A Check of How Well Water Quality Objectives were Achieved in 1986. Victoria, B.C. 71 p.

Savard, J.-P. L. 1985. Fall and winter inventories of ducks on the Fraser River delta and Boundary Bay, 1977-1978. Unpublished report, Canadian Wildlife Service, Delta, B.C. File 9410-2.

Singleton, H.J. 1980. Fraser River Estuary Study: water quality. Acute toxicity of effluents. Fraser River Estuary Study, Ministry of Environment, Victoria. 91 p.

Singleton, H.J. 1983. Trace metals and selected organic contaminants in Fraser River fish. B.C. Ministry of Environment, Water Management Branch, Victoria, B.C., Tech. Paper 2. 114 p.

Slaymaker, O. and L.M. Lavkulich. 1978. A review of land use - water quality interrelationships and a proposed method for their study. Westwater Research Centre, UBC, Tech. Rept. 13. 59 p.

Stancil, D.E. 1980. Fraser River Estuary Study: water quality. Aquatic biota and sediments. Fraser River Estuary Study, Ministry of Environment, Victoria. 187 p.

Standing Committee on the Fraser River Estuary Water Quality Plan. 1990. Status Report on water quality in the Fraser River Estuary -1990. Fraser River Estuary Management Program, New Westminster, B.C. December 1990.

Standing Committee on the Fraser River Estuary Water Quality Plan. 1989. Third Annual Fraser River Estuary Workshop on Research. February 21/22, 1989. 57 p.

Standing Committee on the Fraser River Estuary Water Quality Plan. 1988. Summary of Monitoring and Research Activities Proceedings - Fraser River Estuary Workshop on Research - 1988. 73 p.

Standing Committee on the Fraser River Estuary Water Quality Plan. 1987a. Status Report on Water Quality in the Fraser River Estuary -1987. Fraser River Estuary Management Program, New Westminster, B.C. December 1987. 103 p.

Standing Committee on the Fraser River Estuary Water Quality Plan. 1987b. Summary of Research and Monitoring Activities. Fraser River Estuary Management Program. New Westminster, B.C. September 1987.

Supervisory Coordinating Committee. 1987. Fraser River Estuary Monitoring, Summary Report of the 1986 Effluent Monitoring Program. B.C. Ministry of Environment and Fraser River Harbour Commission. October 1987. 34 p.

Swain, L.G. 1980. Fraser River Estuary Study: water quality. Industrial effluents. Fraser River Estuary Study, Ministry of Environment, Victoria. 195 p.

Swain, L.G. 1983. Stormwater monitoring of a residential catchment area, Vancouver, B.C. B.C. Ministry of Environment. Victoria, B.C. June 1983. 250 p.

Swain, L.G. 1986. A 1985 survey of metals, PCBs and chlorophenols in the sediments, benthic organisms and fish of the lower Fraser River. B.C. Ministry of Environment. Victoria, B.C. June 1986. 50 p.

Swain, L.G. 1989. Coquitlam - Pitt River area, tributaries to the lower Fraser River along the north shore, water quality assessment and objectives. B.C. Ministry of Environment. Victoria, B.C. December, 1989. 140 p.

Swain, L.G. and G.B. Holms. 1985. Fraser-Delta Area, Fraser River Sub-basin From Kanaka Creek to the mouth, water quality assessment and objectives. B.C. Ministry of Environment. Victoria, B.C. November 1985. 193 p.

Swain, L.G. and G.B. Holms. 1988. Fraser-Delta Area, Boundary Bay and its tributaries, water quality assessment and objectives. B.C. Ministry of Environment. Victoria, B.C. February 1988. 167 p.

Swain, L.G. and R.J. Rocchini. 1983. A progress report on the state of water quality in the lower Fraser River. Water Management Branch. 26 p.

Swain, L.G. and D.G. Walton. 1988. Fraser River Estuary Monitoring, report on the 1987 benthos and sediment monitoring program. B.C. Ministry of Environment and Fraser River Harbour Commission. March 1988. 66 p.

Swain, L.G. and D.G. Walton. 1989. Fraser River Estuary monitoring, report on the 1988 fish monitoring program. B.C. Ministry of Environment and Fraser River Harbour Commission. March 1989. 147 p.

Swain, L.G. and D.G. Walton. 1991. Fraser River Estuary Monitoring, Report on the 1990 Sediment Toxicity Program. (In Preparation).

Tetra Tech. 1986a. Development of sediment quality values for Puget Sound. Prepared for EPAN 10, Washington State Departments of Ecology and Natural Resources and the U.S. Army Corps of Engineers.

Tetra Tech. 1986b. Analytical Methods for U.S. EPA priority pollutants and 301(h) Pesticides in tissues from estuarine and marine organisms. Report prepared for the U.S. EPA. Contract 68-01-6938.

U.S. EPA. 1986. Quality Criteria for Water. EPA 440/5-86-001.

Wan, M. 1989. Levels of selected pesticides in farm ditches leading to rivers in the Lower Mainland of British Columbia. Journal Of Environmental Science and Health. B24. p. 198-203.

Waste Management Activity Program Working Group. 1990. A Recommended Waste Management Activity Plan. Prepared for the Management Committee Executive Fraser River Estuary Management Program. October 1990. 133 p.

Water Quality Work Group. 1979. Fraser River Estuary Study, Water Quality, Summary Report of the Water Quality Work Group. Victoria, B.C. December 1979. 176 p.

Water Survey of Canada. 1985. Historical Streamflow Summary: British Columbia to 1984. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 996 p.

Working Committee on Fraser River Estuary Monitoring, A Recommended Approach. 1984. B.C. Ministry of Environment. Victoria, B.C. 42 p.

APPENDICES

APPENDIX I

LEGISLATION AND AGENCY JURISDICTIONS

1.0 FEDERAL LEGISLATION

1.1 *Constitution Act*

The *Constitution Act* (formerly the *British North America Act*) separates the respective jurisdictional authorities of federal and provincial governments in Canada. This division, gives authority over the sea coast and inland fisheries to the parliament of Canada, providing the mandate for the federal government to manage Canada's fisheries. The *Constitution Act* (section 92) gives the provinces legislative control of property and civil rights within their boundaries. Provinces thus own the beds of lakes and rivers and have the jurisdiction to regulate land and water use activities.

1.2 *Fisheries Act*

The departmental mandate of Fisheries and Oceans includes the *Fisheries Act*.

In British Columbia, the provincial government retains jurisdiction over the management of freshwater sportfisheries, water use and waste management.

Section 35 of the *Fisheries Act* administered by the Department of Fisheries and Oceans, prohibits any work or undertaking that may result in the harmful alteration, disruption or destruction of fish habitat. Fish habitat is defined in the Act as follows:

> "Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." - section 31(5).

A 1985 Memorandum of Understanding between Environment Canada and Fisheries and Oceans formalized a process whereby section 36 of the *Fisheries Act* is administered by Environment Canada, in cooperation with the Department of Fisheries and Oceans. Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, thereby incorporating pollution prevention provisions into the *Fisheries Act*.

1.3 *Canada Water Act*

The 1970 *Canada Water Act*, administered by Environment Canada, provides a legislative framework for management of Canada's water resources, through cooperative action by federal and provincial governments.

The *Canada Water Act* is divided into four parts. Part I provides for comprehensive water resource management through joint, federal-provincial basin management agreements. One such agreement was instrumental in the formation of the Fraser River Estuary Study between the federal and provincial Environment ministries. The Fraser River Estuary Management Program is a subsequent agreement under the *Canada Water Act* involving Environment Canada and the B.C. Ministry of Environment and Parks, Fisheries and Oceans and the North Fraser and Fraser River Harbour Commissions.

Another agreement relevant to the Fraser River Estuary Management Program is the Canada/B.C. Water Quality Monitoring Agreement, approved by the federal and provincial environment ministers in October, 1985. The purpose of this agreement is to provide for the coordination and integration of federal and provincial water quality monitoring activities, in a cost-shared or work-shared manner. Under this agreement, water quality monitoring stations have been established at Hope and other upstream sites in the Faser River drainage.

1.4 *Canada Shipping Act*

Enacted in 1970, the *Canada Shipping Act* and its regulations administered by Transport Canada, provide pollution control legislation applicable to maritime transport and safety aspects of recreational boating. Regulations under the Act are specific to oil pollution prevention, dangerous goods shipping and the discharge of general pollutants from ships. The owner of a ship may be liable for cleanup costs associated with spilled bulk cargo such as oil, under the terms of the *Canada Shipping Act* and regulations.

The *Canada Shipping Act* under Part XX contains enabling authority for regulating control of pollution resulting from the operation of vessles of all sizes. At the present time regulations are in effect for the control of oil, bulk cargoes and garbage in respect of registered (Commercial) shipping operating within internal and terratorial waterways. The discharge of sewage is regulated only on the Great Lakes in accordance with the Great lakes Water Quality agreement with the United States, which came into effect in 1978.

Canada is preparing to accede to the Marpol (73/78) convention. Implementation of this international accord will result in reaffirmation of controls over oil, bulk cargoes and garbage and additionally will introduce controls over packaged chemicals and sewage from all commercial shipping in all navigable waterways. Shipping operated within four miles of the nearest shoreline will require sewage holding tanks or on-board treatment plants. Similar regulations will be promulgated for sewage discharge from pleasure craft. The Provinces will designate environmentally sensitive waterways for selective enforcement of holding tank regulations.

The 1952 *Navigable Waters Protection Act* is administered by Public Works Canada. This statute is not directly concerned with water pollution control but can be applied where the dumping of fill material or dredge spoil occurs, or where causeways are constructed in aquatic environments.

1.5 *Transportation of Dangerous Goods Act*

The 1980 *Transportation of Dangerous Goods Act* and its subsequent regulations and amendments are administered by Transport Canada. Dangerous goods are classified into one of nine categories, each requiring special labelling and documentation, depending on the mode of transport. The consignor must provide the carrier with appropriate documentation for each shipment and training and certification are required for individuals handling or transporting dangerous goods. It establishes a manifest system for the interprovincial and international movement of names substances (e.g. specific pesticides) and provides substantial penalities in the event that dangerous goods are illegally handled or transported.

1.6 *Pest Control Products Act*

The most visible federal legislation for regulating pesticides in Canada, the *Pest Control Products Act*, is administered by Agriculture Canada. It provides pesticide registration procedures for manufacturers and government agencies and stipulates labelling and use requirements for pesticides. The intent of the *Pest Control Products Act* is expressed in Section 3(1), which states that it is an offence to manufacture, store, display, distribute or use pesticides under "unsafe conditions". The remaining provisions of the Act and its regulations are designed to provide the authority to achieve this intent.

1.7 *Canadian Environmental Protection Act*

In June 1987 Bill C74 was tabled in the House of Commons introducing the *Canadian Environmental Protection Act* (CEPA).

Administered by Environment Canada and Health and Welfare Canada, this statute streamlined Canadian environmental legislation through repeal of the *Environmental Contaminants Act*, the *Clean Air Act*, the *Ocean Dumping Control Act* and sections of the *Canada Water Act* and the *Department of Environment Act*.

CEPA contains substantial penalties for violators, and provides leadership in the development of nationally consistent environmental quality standards and guidelines. It also makes provision for environmental quality objectives and a network of environmental monitoring stations. Regulation of ocean dumping is part of *CEPA* to control the quality and quantity of wastes dumped at sea. In estuaries, jurisdiction extends upstream to the limit of tidal influence.

1.9 *Boundary Waters Treaty*

Article IV of the Boundary Waters Treaty of 1909 between the United States and Canada states that " . . . waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other".

The provisions of Article IV give Environment Canada, through the Department of External Affairs, the authority to undertake studies necesssary in boundary and transboundary waters and their direct tributaries. These can include long-term water quality data collection, intensive water quality studies, negotiation of Water Quality Objectives, and compliance monitoring for Water Quality Objectives. Furthermore, the Department responds to requests from the International Joint Commission (IJC) in matters referred to the Commission under the provisions of the Boundary Waters Treaty. Under the authority of the Treaty, Environment Canada can also establish principles for boundary waters management, carry out studies in support of the International Joint Commission or other bilateral institutions and provide advice to the government on the acceptability of IJC recommendations.

Other federal acts with limited importance to the protection of water quality and fish habitat exist in Canada. These include the *Food and Drugs Act* and the *Migratory Birds Convention Act*.

2.0 PROVINCIAL LEGISLATION

Under the *Constitution Act* provincial proprietary jurisdiction was provided to British Columbia for all land, water, forests, minerals and all land covered by water. In addition, the provincial government is responsible for the management of freshwater sport and commercial fisheries in B.C.

2.1 *Ministry of Environment Act* (B.C.)

The *Ministry of Environment Act* outlines the authority of the B.C. Ministry of Environment. The agency's responsibilities include the collection of data, the design and implementation of studies and the establishment of Water Quality Objectives.

2.2 *Environment and Land Use Act* (B.C.)

The *Environment and Land Use Act* is the most broadly applicable provincial statute pertinent to natural resource use. Although the Act does not provide the provincial government with direct control over all resource use, its provisions are applicable where other, more specific legislation does not exist. For example, the requirement for the provision of environmental impact assessments for certain industrial and municipal development proposals in the Fraser River Estuary arises from the provisions of the *Environment and Land Use Act*.

2.3 *Environment Management Act* (B.C.)

The *Environment Management Act* empowers the Ministry of Environment to develop management plans and environmental guidelines, to acquire information relative to environmental impact/environmental protection and to take action to prevent environmental damage. Further, the Act enables provincial authorities to initiate appropriate actions in the event of an environmental emergency.

The *Environment Management Act* provides a process for the public to appeal decisions made under other environmental legislation in B.C. (e.g., *Waste Management Act; Pesticide Control Act*).

2.4 *Waste Management Act* (B.C.)

The 1982 *Waste Management Act* is the principal means by which the provincial government controls the pollution of water, air and land. The *Waste Management Act*, administered by B.C. Environment, sets out a framework for the permitting of waste discharges to the environment. This includes establishing the responsibility of air emissions in Greater Vancouver area with the GVRD. It also provides for the collection of fees from all permit holders. Further, the Act provides municipal governments with the opportunity to develop "waste management plans" for comprehensive management of solid and liquid municipal wastes. Under the direction of the Waste Management Branch, the provincial government maintains a federal/provincial referral process through which proposals to discharge wastes are reviewed.

2.5 *Offence Act* (B.C.)

In December 1986, the Ticket Information Fines Regulation and Ticket Administration of the *Offence Act* came into effect. The Act's schedules designate enforcement officers, describe offences and prescribe penalties for a number of provincial statutes including the *Litter Act*, the *Pesticide Control Act*, the *Transport of Dangerous Goods Act*, and the *Waste Management Act*.

With reference to the *Waste Management Act*, tickets may be issued for misdemeanor offences such as the unauthorized acceptance, shipment or storage of hazardous wastes, the failure to report spills or non-compliance with waste discharge permits. Penalties levied through ticket issuance range from $100 to $200. The option also exists to proceed with court action in respect to repeat or other offences.

2.6 *Pesticide Control Act* (B.C.)

Consolidated in 1982, the *Pesticide Control Act*, administered by B.C. Environment, requires that individuals who apply pesticides to public land or water obtain a permit from the B.C. Pesticide Control Branch. The Act further provides the authority for the Pesticide Control Branch to:

- Train and certify new pesticide applicators; and
- Appoint and chair a Pesticide Control Committee to oversee a federal/provincial referral system for the permitting of pesticide use.

In the above referral process, a ten metre Pesticide Free Zone surrounding waterbodies is an established requirement in British Columbia to ensure that fish habitat and potable water supplies are not impacted by pesticide contamination.

2.7 *Health Act* (B.C.)

The *Health Act* provides the B.C. Cabinet with power to pass regulations concerning public health, including those to protect against water pollution. The *Health Act* also provides regulatory power over minor sewage discharges to the ground. Regulations are in place under the *Health Act* to prohibit the improper discharge of solid or liquid wastes into freshwater.

2.8 *Water Act* (B.C.)

The *Water Act* provides the B.C. Ministry of Environment and Parks with the authority to regulate the use of water, including groundwater, in the province. The B.C. government retains rights to all provincial water except where a water licence has been granted. Water licenses specify the source and quantity of water that may be used for purposes ranging from domestic use to hydro electric power generation.

The Act also has seldom used provisions applicable to the protection of water quality.

2.9 *Municipal Act* (B.C.)

The *Municipal Act* requires that municipalities adopt official community plans and associated zoning bylaws. Municipal councils have the power to regulate water quality in local jurisdictions through the passage of bylaws which prohibit the discharge of materials which pollute or obstruct waterbodies.

2.10 *Greater Vancouver Sewerage and Drainage District (GVS & DD) Act*

The *GVS & DD Act*, proclaimed by the Provincial Government in 1956, created the Greater Vancouver Sewerage and Drainage District. The objectives of the corporation are the construction, maintenance, operation, and administration of the major sewerage and drainage facilities in the Greater Vancouver Area in accordance with the Rawn Report (a master plan for sewerage and drainage facilities completed in 1953) or updated versions thereof.

In 1984, the District was designated a Sewage Control Area under Section 17 of the *Waste Management Act*. Under this section, the District's Sewage Control Manager may, prohibit or regulate the discharge of any type of waste other than domestic sewage into a sewage facility. Under Section 18, the District's Board may make bylaws respecting the direct or indirect discharge of wastes into any sewer or drain connected to a sewage facility operated by the District.

3.0 DEVELOPMENT PROPOSAL REVIEW MECHANISMS

As noted above, federal/provincial referral systems (e.g., Waste Management Branch and Pesticide Control Branch referral systems) are established and function for the review of development proposals which have the potential to damage fish habitat or degrade water quality. In addition, under the authority of the Federal Environmental Assessment and Review Process, the Regional Screening and Coordinating Committee reviews federally-sponsored projects and other major developments to ensure adequate environmental safequards are included to protect aquatic resources.

Under FREMP, an interagency Environmental Review Committee has been established to provide a forum for consultation during review of major development projects in the Fraser River estuary (Section 1.3). Projects such as dredging, dock construction, log storage and marina development are examined under the direction of a Lead Agency. That agency determines the level of review required, the degree of other agency involvement and ultimately, whether tenure will be granted and/or construction approved.

APPENDIX II

MINISTRY OF ENVIRONMENT PROVISIONAL WATER QUALITY OBJECTIVES FOR THE FRASER RIVER ESTUARY

TABLE 1
PROVISIONAL WATER QUALITY OBJECTIVES FOR THE FRASER RIVER SUB-BASIN FROM KANAKA CREEK TO THE MOUTH

(Prepared and Issued by B.C. Ministry of Environment)

WATER BODIES	FRASER RIVER			STURGEON AND ROBERTS BANKS
	MAIN STEM	NORTH AND MIDDLE ARMS	MAIN ARM	
Designated Water Uses	Aquatic life, wildlife, recreation, livestock, irrigation			Aquatic life, wildlife, recreation
Fecal Coliforms[1]	≤1 000 MPN/100 mL geometric mean April - October 4 000 MPN/100 mL maximum April - October			≤200 MPN/100 mL geometric mean and ≤400 MPN/100 mL 90th percentile, at bathing beaches from June through August
Suspended Solids[2]	not applicable	10 mg/L maximum increase (upstream ≤100 mg/L) 10% maximum increase (upstream ≥100 mg/L)	not applicable	
Total Chlorine Residual[3]	not applicable		0.002 mg/L maximum	
Un-ionized Ammonia -N[4]	not applicable	0.03 mg/L maximum, ≤0.007 mg/L average		
Dissolved Oxygen	7.75 mg/L minimum			9 mg/L minimum
pH[5]	6.5 - 8.5			not applicable
Total Copper[4]	not applicable	For hardness ≥ 35 mg/L: 0.006 mg/L maximum, ≤0.004 mg/L average or 20% maximum increase, whichever is greater For hardness < 35 mg/L: 0.004 mg/L maximum, ≤0.003 mg/L average or 20% maximum increase, whichever is greater		not applicable
Total Lead[4]	not applicable	0.010 mg/L maximum ≤0.003 mg/L average		not applicable
Total Zinc[4]	not applicable	≤0.05 mg/L average 0.10 mg/L maximum		not applicable
Chlorophenols[6],[7],[8]	10 ppb (dry weight) maximum in bottom surface sediments 0.1 ppm (wet weight) maximum in fish muscle 0.2 µg/L maximum in water			10 ppb (dry weight) maximum in bottom surface sediments
PCB's[7],[8],[9]	30 ppb (dry weight) maximum in bottom surface sediments 0.5 ppm (wet weight) maximum in fish muscle			not applicable

TABLE 1 - CONT'D
PROVISIONAL WATER QUALITY OBJECTIVES

Note: The objectives apply to discrete samples from all parts of the waterbodies, except from initial dilution zones of effluents. These excluded initial dilution zones in the Fraser River are defined as extending up to 100 m downstream (or upstream at times of tide reversal) from a discharge, and occupying no more than 25% of the stream width around the discharge point, from the bed of the stream to the surface. These excluded initial dilution zones in marine waters are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody. This exclusion does not apply to objectives for fish as noted in 8 below.

[1] The geometric mean and the 90th percentile are calculated from at least five weekly samples taken in a period of 30 days. The recreation objective (200-400/100 mL) applies during the recreation season and the irrigation objective (1 000 - 4 000/100mL) applies during the irrigation season.

[2] The increase (in mg/L, or %) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels.

[3] Since the objective is less than the minimum detectable concentration, it will be necessary to estimate the receiving water concentration using effluent load and stream flow. The objective applies only if sewage effluent is chlorinated.

[4] The average is calculated from at least five weekly samples taken in a period of 30 days.

[5] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is exceeded.

[6] The term chlorophenol means the sum of tri-, tetra-, and pentachlorophenol which may be present in water, sediment or fish.

[7] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objective.

[8] The objective applies only to fish muscle tissue, not the whole fish or organs, of a fish of any species caught in any part of the sub-basin, including the initial dilution zones of effluents.

[9] The term PCB's applies to the sum of a Aroclor 1242, 1254, and 1260, which may be present in water, sediment or fish.

Source: Swain and Holms 1985

TABLE 2
PROVISIONAL WATER QUALITY OBJECTIVES FOR THE LITTLE CAMPBELL RIVER, NICOMEKL RIVER, SERPENTINE RIVER, THEIR TRIBUTARIES, AND BOUNDARY BAY

(Prepared and Issued by B.C. Ministry of Environment)

Water Bodies	Little Campbell River and tributaries	Mahood, Hyland and Latimer Creeks	Serpentine River	Nicomekl River	Anderson and Murray Creeks	Boundary Bay
Designated Water Uses / Characteristics	Aquatic life, wildlife, irrigation, livestock watering, primary-contact recreation	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, primary-contact recreation
Fecal Coliforms[1]	≤200 MPN/100 mL geometric mean (April to October) ≤400 MPN/100 mL 90th percentile (April to October)	≤1000 MPN/100 mL geometric mean (April-October) ≤4000 MPN/100 mL maximum (April-October)				≤200 MPN/100 mL geometric mean (April to October) ≤400 MPN/100 mL 90th percentile (April to October)
	not applicable	≤200 MPN/100 mL geometric mean (year-round) (long-term objective)				≤14 MPN/100 mL median (year-round) (long-term objective) ≤43 MPN/100 mL 90th percentile (year-round) (long-term objective)
Suspended Solids[2]	10 mg/L maximum increase (upstream ≤100 mg/L) 10% maximum increase (upstream >100 mg/L)					
Substrate Sedimentation[2]	No significant increase (95% confidence level) by weight in particulate matter for particles <3 mm in diameter					
Turbidity[2]	5 NTU maximum increase (upstream ≤50 NTU) 10% maximum increase (upstream >50 NTU)					
Total Ammonia-N	See Tables 3 and 4					not applicable
Nitrite-N	See Table 5					not applicable
Periphyton Chlorophyll-a[2]	50 mg/m^2 maximum average	100 mg/m^2 maximum average: long-term objective		100 mg/m^2 maximum average		not applicable
Dissolved Oxygen	6.0 mg/L minimum (June-October)	8.0 mg/L minimum	6.0 mg/L minimum (June-October)		8.0 mg/L minimum	6.5 mg/L minimum 9.0 mg/L minimum (long-term objective)
	11.0 mg/L minimum (when fish salmonid eggs and larvae or alevin are present)					
	8.0 mg/L long-term objective for minimum (June-October)	not applicable	8.0 mg/L minimum (June-October) (long-term objective)		not applicable	

TABLE 2 (Continued)

Water Bodies	Little Campbell River and tributaries	Mahood, Hyland and Latimer Creeks	Serpentine River	Nicomekl River	Anderson and Murray Creeks	Boundary Bay
Designated Water Uses / Characteristics	Aquatic life, wildlife, irrigation, livestock watering, primary contact recreation	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, primary-contact recreation
pH [4]	6.5 - 8.5	6.5 - 8.5 or 0.2 maximum increase (upstream > 8.5)				not applicable
Total Lead[5]	not applicable			0.005 mg/L average 0.010 mg/L maximum	not applicable	
PCBs [6],[7],[8]	Not applicable	0.001 µg/L maximum in water 0.03 µg/g (dry-weight) maximum in bottom surface sediments 0.1 µg/g (wet-weight) in whole small fish subject to predation 0.5 µg/g (wet-weight) in muscle of larger fish consumed by man		not applicable		0.03 µg/g (dry-weight) maximum in bottom surface sediments

Note: The objectives apply to discrete samples from all parts of the waterbodies, except from initial dilution zones of effluents. These excluded initial dilution zones are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50% of the stream width around the discharge point, from the bed of the stream to the surface. These excluded initial dilution zones in the Bay are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody.

[1] The geometric mean, median, and the 90th percentile are calculated from at least five samples taken weekly in a period of 30 days. The recreation objective (200-400/100 mL) applies during the recreation season and the irrigation objectives (1000-4000/100 mL) applies during the irrigation season.

[2] The increase (in mg/L, NTU or %) is over levels measured at a background site or at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels. In Boundary Bay, "control" samples should be obtained from areas of similar physical characteristics to those areas where measurements near a discharge are to be made.

[3] The average is calculated from at least five randomly located samples taken from natural substrates at each site on any one sampling date.

[4] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is exceeded.

[5] The average is calculated from at least five weekly samples taken in a period of 30 days.

[6] The objectives do not apply to Hyland or Latimer Creeks.

[7] The term PCBs applies to the sum of Aroclor 1242, 1254, and 1260, which may be present in water, sediment or fish.

[8] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objectives. Also, the objective applies only to fish of any species caught in any part of the creeks or river, including the initial dilution zones of effluents.

TABLE 3
MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp.																				
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

Source: Nordin and Pommen 1986

TABLE 4

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE

(mg/L-N)

pH	Temp.																				
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in Table 4.
- each measured value is compared to the corresponding individual values in Table 4. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding objective values in Table 4.

Source: Nordin and Pommen 1986

TABLE 5

MAXIMUM AND 30-d AVERAGE NITRITE (N) CONCENTRATIONS

Chloride Concentration (mg/L)	Maximum Nitrite-N Concentration (mg/L)	30-d Average Nitrite-N Concentration* (mg/L)
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

*the 30-d average chloride concentration should be used to determine the appropriate 30-d average nitrite objective.

Source: Nordin and Pommen 1986

TABLE 6
PROVISIONAL WATER QUALITY OBJECTIVES FOR TRIBUTARIES TO THE FRASER RIVER ALONG THE NORTH SHORE
(Prepared and Issued by B.C. Ministry of Environment)

WATER BODIES	Kanaka Creek	Pitt Lake	Alouette Lake	Pitt River	Alouette River	N. Alouette River	Coquitlam River	Scott and Hoy creeks	Or Creek	Brunette River	Still Creek	Deer and Burnaby Lake
DESIGNATED WATER USES / CHARACERISTICS	Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation	Aquatic life, wildlife					Aquatic life, wildlife recreation, livestock, irrigation			Aquatic life, wildlife		Aquatic life, wildlife, primary-contact recreation (long-term)
		drinking water (disinfection only)		drinking water (complete treatment plus disinfection)								
		recreation		N/A	recreation							
		livestock, irrigation										
Fecal Coliforms¹,²,³	≤200/100 mL maximum (short-term) ≤100/100 mL 90th percentile (long-term)	≤10/100 mL 90th percentile		≤200/100 mL geometric mean (short-term) ≤100/100 mL 90th percentile (long-term)		≤100/100 mL 90th percentile	≤200/100 mL geometric mean ≤100/100 mL 90th percentile		≤10/100mL 90th percentile	not applicable		≤200/100 mL geometric mean (long-term) ≤400/100 mL 90th percentile (long-term)
Escherichia coli ¹,²,³	≤200/100 mL maximum (short-term) ≤100/100 mL 90th percentile (long-term)	≤10/100 mL 90th percentile		≤77/100 mL geometric mean (short-term) ≤100/100 mL 90th percentile (long-term)		≤100/100 mL 90th percentile	≤100/100 mL 90th percentile ≤77/100 mL geometric mean		≤10/100mL 90th percentile	not applicable		≤77/100 mL geometric mean (long-term)
Enterococci ¹,²,³	≤50/100 mL maximum (short-term) ≤25/100 mL 90th percentile (long-term)	≤3/100 mL 90th percentile		≤200/100 mL geometric mean (short-term) ≤25/100 mL 90th percentile (long-term)		≤25/100 mL 90th percentile	≤25/100 mL 90th percentile ≤20/100 mL geometric mean		≤25/100mL 90th percentile	not applicable		≤20/100 mL geometric mean (long-term)
Pseudomonas aeruginosa ¹,³	not applicable						≤2/100 mL 75th percentile		not applicable			≤2/100 mL 75th percentile (long-term)
Suspended Solids³	10 mg/L maximum increase (upstream ≤ 100 mg/L) 10% maximum increase (upstream > 100 mg/L)											
Substrate Sedimentation³	No significant increase by weight in particulate matter <3 mm in diameter										not applicable	
Turbidity³	1 NTU maximum increase (upstream < 5 NTU) 5 NTU maximum increase (upstream ≤ 50 NTU) 10% maximum increase (upstream > 50 NTU)											

TABLE 6 (Continued)

WATER BODIES	Kanaka Creek	Pitt Lake	Alouette Lake	Pitt River	Alouette River	N. Alouette River	Coquitlam River	Scott and Hoy creeks	Or Creek	Brunette River	Still Creek	Deer and Burnaby lakes
DESIGNATED WATER USES / CHARACERISTICS	Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation	Aquatic life, wildlife					Aquatic life, wildlife recreation, livestock, irrigation			Aquatic life, wildlife		Aquatic life, wildlife, primary-contact recreation (long-term)
		drinking water (disinfection only)		drinking water (complete treatment plus disinfection								
		recreation		N/A	recreation							
		livestock, irrigation										
Total Ammonia-N	See Tables 3 and 4											
Nitrite-N^1	≤0.02 mg/L average 0.06 mg/L maximum										See Table 4	
Periphyton^4 Chlorophyll-a	≤50 mg/m^2 average	not applicable		≤100 mg/m^2 average			≤50 mg/m^2 average			≤100 mg/m^2 average		not applicable
Total Phosphorus^{10}	not applicable											≤0.015 mg/L (long-term)
Dissolved Oxygen^2	8.0 mg/L minimum 11.0 mg/L minimum when embryo or larvae present (November-March)	Not Applicable		8.0 mg/L minimum 11.0 mg/L minimum when embryo or larvae present (November-March)						8.0 mg/L minimum	6.0 mg/L minimum (short-term) 8.0 mg/L minimum (long-term)	
										11.0 mg/L minimum when embryo or larvae present (November-March) (long-term)		
pH^3,^{5}	6.5 - 8.5 (long-term)	6.5 - 8.5 or maximum 0.2 change (upstream <6.5)								6.5 - 8.5		
Total Chromium^2	not applicable									0.020 mg/L maximum (long-term)		
Total Copper^2,^{4},^{7}	not applicable									0.005 mg/L maximum (long-term) (hardness >30 mg/L) 0.004 mg/L maximum (long-term) (hardness: 20-30 mg/L) ≤0.002 mg/L average (long-term) 30 µg/g (dry-weight) maximum in sediments (long-term)		

TABLE 6 (Continued)

WATER BODIES	Kanaka Creek	Pitt Lake	Alouette Lake	Pitt River	Alouette River	N. Alouette River	Coquitlam River	Scott and Hoy creeks	Or Creek	Brunette River	Still Creek	Deer and Burnaby Lake
DESIGNATED WATER USES / CHARACERISTICS	Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation	Aquatic life, wildlife					Aquatic life, wildlife recreation, livestock, irrigation			Aquatic life, wildlife		Aquatic life, wildlife, primary-contact recreation (long-term)
		drinking water (disinfection only)		drinking water (complete treatment plus disinfection								
		recreation		N/A	recreation							
		livestock, irrigation										
Total Lead[2,4,7,8]	not applicable									0.018 mg/L maximum (long-term) ≤0.004 mg/L average (long-term)		0.012 mg/L maximum (long-term) ≤0.004 mg/L average (long-term)
										0.8 µg/g (wet-weight) maximum in edible fish flesh 5 µg/g (dry-weight) maximum in sediments (long-term)		
Total Mercury[2,4,7,8]	not applicable									0.1 µg/L maximum (long-term) ≤0.02 µg/L average (long-term) 0.5 µg/g (wet-weight) maximum in edible fish flesh 0.07 µg/g (dry-weight) maximum in sediments (long-term)		
Total Zinc[2,7]	not applicable									0.03 mg/L maximum (long term) 70 µg/g (dry-weight) maximum in sediments (long-term)		
Chlorophenols[6,7,8]	not applicable			0.2 µg/L maximum in water 0.1 µg/g (wet weight) maximum in fish muscle 0.01 µg/g (dry weight) maximum in bottom surface sediments	not applicable							

TABLE 6 (Continued)

Note:

The objectives apply to discrete samples from all parts of the water bodies, except from initial dilution zones of effluents. These excluded initial dilution zones are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50% of the stream width around the discharge point, from the bed of the stream to the surface. In the Pitt River, the initial dilution zone will occupy no more than 25% of th stream width, and can extend up to 100 m upstream from a discharge at times of tide reversal. These excluded initial dilution zones in lakes are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the water body. This exclusion does not apply to objectives for fish as noted below.

[1] The average, geometric mean, and the 75th and 90th percentiles are calculated from at least five weekly samples taken in a period of 30 days. For values recorded as less than the detection limit, the detection limit itself should be used in calculating the statistic.

[2] Long-term objectives indicate situations where existing water quality does not suit all desired water uses, but it is considered feasible to improve the water quality over time. Short-term objectives protect water uses to a certain degree until the long-term objectives can be achieved.

[3] The increase (in mg/L, NTU, or%) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels. For substrate sedimentation, the increase is measured on the basis of the averages of at least three samples collected upstream and downstream, and the significant increase will be defined as no difference greater than 10%. In lakes, substrate sedimentation will usually be measured at the mouths of creeks where fish spawn.

[4] The average is calculated from at least five randomly located samples from natural substrates at each site on any one sampling date.

[5] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is not achieved.

[6] The term chlorophenol means the sum of tri-, tetra-, and pentachlorophenol which may be present in water, sediment or fish.

[7] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objective.

[8] The objective applies only to fish muscle tissue, not the whole fish or organs, of a fish of any species caught in any part of the sub-basin including the initial dilution zones of effluents.

[9] In the Coquitlam River, the objectives of ≤100/100 mL fecal coliforms, ≤100/100 mL Escherichia coli, and ≤25/100 mL enterococci, as 90th percentiles apply only between Coquitlam Lake and the southern boundary of the Coquitlam River Park. The objectives of ≤200/100 mL fecal coliforms, ≤77/100 mL Escherichia coli, and ≤20/100 mL enterococci, as geometric means and <2/100 mL Pseudomonas aeruginusa as the 75th percentile, apply only to the Coquitlam River below Coquitlam River Park and to Scott and Hoy creeks.

[10] The objective applies only in Burnaby Lake at a depth of 1 metre, and is the average of monthly measurements from April to October.

Source: Swain 1989

APPENDIX III

MONITORING ROLES IN THE REGION

Greater Vancouver Sewerage and Drainage District (GVS & DD)

The GVS & DD is the major discharger of treated municipal wastewater to the receiving environment via sewage treatment plant outfalls. The District's facilities also include combined sewer overflows which discharge raw effluent on an occasional basis. In addition, the District is responsible for certain storm drainage facilities.

Sewage treatment plant influents and effluents are routinely monitored for standard characteristics (e.g. suspended solids, biochemical oxygen demand), metals and toxicity. The District perceives its role to include monitoring these wastewater flows not only as a permit requirement (in the case of effluents), but also because results of this testing can be used to assess the operation of the plants, effectiveness of source control programs, and for planning improvements either to the plants or to pretreatment facilities.

Discharges from combined sewer overflows and stormwater drainage facilities are not routinely monitored and require additional study. The District perceives its role to include monitoring these discharges as required for planning future facilities and improvements. The District may also undertake (on a case by case basis) some monitoring of stormwater discharges on behalf of member municipalities at their cost.

The District recognizes that impacts from the noted discharges can be significant in the immediate area of the discharge. Therefore, monitoring in the immediate impact zone of District facilities would be primarily the role of the District. Beyond this zone, monitoring would address overall quality of a waterbody, on which there can be many influences. Therefore, the district believes that it does not have the primary responsibility for monitoring beyond the immediate impact zone of its own facilities and in fact, many agencies are involved in monitoring such areas.

Exceptions to the above however, can arise where many District outfalls impact on the same body of water (e.g. North Arm). In such areas, sewerage planning needs to be based on the cumulative effect of these discharges on the waterbody. Therefore, in such cases, the District's monitoring role could be extended beyond the immediate impact zones in a cooperative program with other agencies.

An example of the District's broader role is the monitoring of metropolitan bathing beaches for fecal coliforms. Since District facilities have the potential to contribute major sources of fecal coliforms to the receiving environment, which could have widespread impacts on recreational use during the warmer months, the District is required by Waste Management Permit to carry out bathing beach monitoring.

Federal Agencies

The Department of Fisheries and Oceans and the Department of the Environment have responsibilities for research and monitoring within the FREMP study area.

Environment Canada's water quality monitoring programs are conducted by the Canadian Wildlife Service (CWS), Inland Waters (IW) and Environmental Protection (EP).

The mandate of CWS is to ensure the health and well being of migratory birds. Most of its monitoring is issue oriented. Currently a major effort in the FREMP study area is monitoring of the great blue heron population of the Fraser River Estuary.

Inland Waters has a mandate to collect, analyze, and interpret ambient water quality data within the Fraser River Estuary. The data are used to develop Water Quality Objectives and to develop an ongoing monitoring program for the estuary. The ultimate goal of these activities is to protect the users of the estuary and maintain ambient water quality conditions.

Environmental Protection monitors effluents and receiving environments, in the FREMP study area related to its lead administrative role of Section 36 of the *Fisheries Act*. Receiving environments are monitored to assess site specific impacts (i.e. discharge related), as well as to define ambient conditions in a water body. The effects of contaminant inputs on water, sediment and biota are evaluated and efforts made to relate them to contaminant sources. Effluent monitoring is done to evaluate the need for and effectiveness of existing STP and industrial in-plant pollution control processes.

EP also maintains an emergency response capability for contaminant spills. Disposal via ocean dumping is controlled under the *Canadian Environmental Protection Act* managed by EP through a referral system. Through its shellfish growing water quality certification program, EP monitors the acceptability of shellfish growing areas for harvesting.

In conjunction with EP, or independently, DFO conducts research and monitoring of effluents and receiving waters to determine whether specific discharges or groups of discharges are causing impacts on fish and fish habitat. Such monitoring may be done *in situ* or by the use of laboratory bioassays, water, tissue, sediment and/or effluent sampling.

Monitoring in support of specific research objectives (e.g. the effects of sewage discharges on fish) is carried out by DFO in conjunction with controlled laboratory studies. Effluents and spilled materials are sampled by DFO (often in cooperation with EP) for potential legal action under the *Fisheries Act*. Fish and shellfish are monitored for levels of specific contaminants to determine whether man's use of fish is endangered in specific areas. DFO also provides data on fish stocks, timing and abundance; expertise on the physical aspects of fish habitats and their restoration; and is involved with research and development of new biota monitors for chlorinated organic uptake (e.g. high lipid fish) and researches the effects of selected pesticides on fish.

Provincial Agencies

The Provincial government has the mandate for monitoring discharges, zone of influence impacts, and ambient environmental conditions in all waterbodies in British Columbia.

The Ministry of Environment carries out several types of monitoring programs in the FREMP study area. These include monitoring permitted discharges, conducting environmental impact assessments, responding to complaints and environmental emergencies carrying out long-term trend monitoring programs and checking attainment of Water Quality Objectives.

Permitted discharges are monitored by Waste Management to determine permit compliance. This includes monitoring effluents, groundwater and surface water at sites under permit (i.e. refuse and effluent).

Environmental impact assessments are also carried out by Waste Management. This includes monitoring in the immediate receiving environment in a more intensive manner than for permitted discharges. Such monitoring is often toxicologically oriented.

Monitoring is also conducted by Waste Management to determine if a problem exists and to determine its extent following reports from the public (complaints) and to respond to environmental emergencies. Further monitoring may follow to determine if clean up procedures are effective and to determine when safe levels of contaminants have been reached.

Long-term monitoring is also conducted by Water Management and Waste Management to gather background water quality information (e.g. Fraser River at Hope; lakes being studied for potential impacts from acid rain; and sampling in the estuary through the Fraser River Harbour Commission). Although some data from all of the above programs can be used in the evaluation of Water Quality Objectives, monitoring which is specifically aimed at formulating and evaluating Water Quality Objectives is also carried out by Waste Management and Water Management Branches.

The B.C. Ministry of Health monitors fecal coliform concentrations at bathing beaches (e.g. Boundary Bay is monitored by the Boundary Health Unit) during the recreation season.

Municipalities

Municipalities are responsible for the general health of the public in their area. The most important health issue relating to water quality in the receiving water environment is fecal contamination at bathing beaches. Municipalities monitor fecal coliform levels at beaches to ensure that public safety is maintained, if this role is not assumed by Provincial Health or GVS & DD monitoring.

Some municipalities also conduct routine and problem oriented stormwater monitoring as part of their responsibility for discharges to receiving waters.

Non-Governmental Organizations (universities etc.)

This sector's research helps to provide the analytical tools and understanding of the ecosystem to assist a monitoring program. Specific areas include:

1. Providing a better understanding of the spatial and temporal distribution of components of the aquatic ecosystem and information on how the ecosystem components interact. This functional knowledge assists monitoring agencies with program design and assessment.

   Assessing the impact of specific pollutants on components of the aquatic ecosystem. Studies are especially needed on long-term effects of persistent contaminants. The sources of persistent contaminants need to be better documented and an appropriate strategy developed to regulate these contaminants at their source.

3. Researching contaminants, useful bioassay organisms, and biological indicators of water quality conditions to assist in a monitoring network. These techniques are especially useful in determining long-term trends and the effect of sporadic contaminant discharges.

4. Researching the behaviour of contaminants. This is a very broad research area and requires ongoing desk analysis to keep up with current research, as well as local research initiatives to study any specific aquatic environment.

5. Assisting the validity of existing monitoring programs and helping to design new programs within a sound statistical framework.

6. Developing and assessing new analytical techniques for the concentration, isolation and identification of trace pollutants in the aquatic ecosystem. There is a special need for more efficient, inexpensive techniques to investigate organic contaminants.

7. Identifying an efficient process for communicating research findings to managers of water quality so that they can integrate these findings into their monitoring program. Also communicating research needs identified by water quality managers back to the research community.

Three separate Port Authorities are involved in the study area. These are the North Fraser Harbour Commission which has jurisdiction along the North Arm of the Fraser River to New Westminster; the Fraser River Harbour Commission, which has jurisdiction along the Main Arm and the Main Stem of the Fraser River below Kanaka Creek; and the Port of Vancouver, which has jurisdiction on Sturgeon and Roberts Banks (as well as Burrard Inlet and English Bay).

APPENDIX IV

QUALITY ASSURANCE/QUALITY CONTROL

There is no point in collecting data which cannot be used because they are not reliable. Therefore all monitoring programs must include quality assurance as an integral component so as to guarantee that all data collected are indeed both reliable and useful.

Ideally monitoring data should be both highly accurate and highly precise, should have extremely low limits of detection and should be accompanied with complete documentation for every detail as to how the measurements were made. However, there are practical limitations upon technical feasibility, upon budgets and upon program schedules which must be taken into account. These limitations are best coped with through formal written plans, both to organize the program in a scientific manner and to ensure that all people involved have a common understanding of strengths and limitations of the program.

Usually there are two main components to these written plans: the Project Plan and the Quality Assurance (or QA) Plan.

The Project Plan must establish clear objectives for the data quality, including precise statement of the use which will be made of the collected results. This use should be set forth in as great detail and in as mathematical of terms as possible, for example: "Water samples will be collected at site X once a month for the duration of the project so as to ascertain whether the formal water quality objective for copper of 3 micro grams per litre (µg/L) is ever exceeded, and if so whether the rate of exceedance has changed over the course of the study especially during low flow conditions." (Of course such statements will usually be made in tables rather than in the text.)

The Project Plan should also include:

- rationale for choice of sampling location & sample type,
- rationale for choice of sampling schedule & replication,
- rationale for choice of each variable & methodology.

The Quality Assurance Plan will ensure that QA goals are integrated into every phase of the project. Every phase means just that -- right from vetting that the Project Plan does indeed have clear objectives, to checking that the sample bottles are not contaminated, to checking that all procedures are recorded, to checking that samples were collected properly and without contamination, to checking that all staff are properly trained both as to safety and as to scientific aspects of their jobs, checking that all samples collected were analyzed, checking that all data analyzed did become recorded on computer, checking that computing protocols prevent manipulation of the data, etc. Such comprehensive checks are only possible if written protocols are put into place, and a formal QA Plan implemented.

The QA Plan should include the following: statement of the goals & objectives of the study project; statement as to person or persons responsible for implementing the QA Plan (if several persons are identified then their precise roles must be spelled out); precise statement of the data quality objectives. These data quality objectives must include tabulations as to specific numeric objectives for accuracy, precision, completeness, and comparability, and should also include specific objectives as to maximum times between sample collection and analysis, as to maximum times between sample collection and data reporting (i.e. turnaround time), and as to maximum time a laboratory will hold onto samples after results have been reported.

Such objectives will be study-specific and variable specific. However, so as to set a starting point, it would be fair to say that any program having accuracy, precision or comparability worse than 50% for more than 10% of samples would be in serious difficulty; hopefully more stringent objectives would be set. Completeness should exceed 90%. Time sensitive variables must be analyzed within specified hours from sample collection, labs should strive to have all analyses completed and reported within 45 days of receipt and it is suggested that labs retain samples for at least 30 days after data reporting.

The QA Plan should additionally include specific protocols for sample collection, for sample handling and preservation, and for lab procedures; these protocols often are published as one or more separate documents. Lab procedures must include housekeeping measures such as bottle washing as well as details as to analytical methodologies and calibration procedures. Also the QA Plan must ensure that all monitoring data and QA data are kept in safe custody.

The QA Plan must also specify procedures and reporting requirements for internal quality control (QC) checks, for independent QA audits, for preventive maintenance of all equipment, for routine procedures of data validation (i.e. replicate samples, spiked samples, blanks of various sorts, round robin participation and analysis of standard reference materials). The QA Plan should also indicate what remedial measures must be undertaken should any of the routine QC or QA procedures identify problems.

Realizing that these validation procedures should be study and variable-specific, as a starting point one might consider the following minimal program which is adapted from a draft prepared for the U.S. EPA QA Program (PTI Environmental Services 1990):

- one trip blank (de-ionized (DI) water that remains in its bottle from lab to field and back to lab, usually lid removed briefly at a field location) per cooler and bottle type per trip.

- not fewer than 10% (or 2 samples, whichever is greater) of samples from a sampling trip should be field blanks (i.e. DI water that has passed through all field sample handling procedures), equipment rinsates or matrix spike samples.[1]

- not fewer than 10% (or 2 samples, whichever is greater) from a sampling trip should have been collected in duplicate or replicate. Where heterogeneity might be a problem, not fewer than five replicate samples should be collected[1].

- not fewer than 10% (or 2 samples, whichever is greater) from a sampling trip should be reanalysed at the laboratory to yield confirmed results[1].

- laboratories should maintain their QC records for ready inspection, and should publish and regularly update both tables of detection limits and quantitation limits, and results of analyses of standard reference materials.

It is important to appreciate that an important goal of QA is to ensure that data are regularly reviewed to ensure the Study Project's objectives are in fact being met, and to put remedial measures in place where the objectives are not being met. Thus as data are being collected, the results should be interpreted on a timely basis towards improving the overall monitoring program. The essence of QA is not just accurate and precise data, but also timely and meaningful results.

---

[1] The 10% figure should be doubled when QA problems need to be resolved.

When discussing matters of QA, questions often arise as to the relationship between detection limits, quantitation limits and water quality criteria. The detection limit is the lowest amount of a substance which can be discerned above the random "noise" of the analytical procedure; the quantitation limit is the lowest level at which a substance can be accurately measured. Generally the quantitation limit is about 3 or more times greater than the detection limit.

- Both the detection limit and the quantitation limit must be clearly stated for every procedure.
- Values below the quantitation limit must be clearly flagged as estimates; values below the detection limit should not be reported.
- If data are to be compared to some criterion value, then the method of analysis used must have a quantitation limit not greater than one-third of this criterion level, and preferably less than one-tenth of the criterion.

APPENDIX V

LIST OF CRITERIA

The following are a listing of some criteria available from different jurisdictions. This list will change through time as new criteria are developed and those listed herein are revised.

B.C. MOE WATER QUALITY CRITERIA

Butcher, G.A. 1988. Water Quality Criteria For Aluminum. Ministry of Environment and Parks. Victoria, B.C.

Nagpal, N.K. 1987. Water Quality Criteria For Lead. Ministry of Environment. Victoria, B.C.

Nagpal, N.K. 1989. Water Quality Criteria for Mercury Ministry of Environment. Victoria, B.C.

Nordin, R.N. 1985. Water Quality Criteria For Nutrients and Algae. Ministry of Environment. Victoria, B.C.

Nordin, R.N. 1990. Water Quality Criteria For Ammonia in Seawater. Ministry of Environment. Victoria, B.C.

Nordin, R.N. and L.W. Pommen. 1986. Water Quality Criteria For Nitrogen (Nitrate, Nitrite, and Ammonia). Ministry of Environment and Parks. Victoria, B.C.

Singleton, H.J. 1987. Water Quality Criteria For Copper. Ministry of Environment and Parks. Victoria, B.C.

Singleton, H.J. 1989. Water Quality Criteria For Chlorine. Ministry of Environment. Victoria, B.C.

Singleton, H.J. 1986. Water Quality Criteria For Cyanide. Ministry of Environment. Victoria, B.C.

Singleton, H.J. 1985. Water Quality Criteria For Particulate Matter. Ministry of Environment. victoria, B.C.

Swain, L.G. 1986. Water Quality Criteria For Molybdenum. Ministry of Environment and Parks. Victoria, B.C.

Warrington, P.D. 1988. Water Quality Criteria For Microbiological Indicators. Ministry of Environment and Parks. Victoria, B.C.

Warrington, P.D. 1990. Water Quality Criteria For Fluoride. Ministry of Environment. Victoria, B.C.

FEDERAL WATER QUALITY CRITERIA

Environment Canada, Inland Waters Directorate, Water Quality Branch (D.M. Trotter, A. Baril, M.P. Wong, and R.A. Kent). 1990. Canadian Water Quality Guidelines For Atrazine. Scientific Series No. 168. Ottawa, Ontario.

Environment Canada, Inland Waters Directorate, Water Quality Branch (D.M. Trotter, M.P. Wong, and R.A. Kent). 1990. Canadian Water Quality Guidelines For Glyphosate. Scientific Series No. 170. Ottawa, Ontario.

Environment Canada, Inland Waters Directorate, Water Quality Branch (B.D. Pauli, R.A. Kent, and M.P. Wong). 1990. Canadian Water Quality Guidelines For Atrazine. Scientific Series No. 179. Ottawa, Ontario.

U.S. EPA WATER QUALITY CRITERIA

United States Environmental Protection Agency. 1976. Quality Criteria For Water. July 1976.

United States Environmental Protection Agency. 1985. Water Quality Criteria. Federal Register, Volume 50, Number 145, July 29, 1985.

United States Environmental Protection Agency. 1986. Quality Criteria For Water, 1986. Office of Water Regulations and Standards. Washington, D.C. 20460. EPA 440/5-86-001.

United States Environmental Protection Agency. 1986. Ambient Water Quality Criteria For Dissolved Oxygen. Criteria and Standards Division, US EPA. Washington, D.C. EPA 44015-86-003.

United States Environmental Protection Agency. 1987. Ambient Aquatic Life Water Quality Advisories For Tributyltin. Office of Research and Development, Environmental Research Laboratories, Duluth, Minnesota and Narragansett, Rhode Island.